

Easier Done Than Said

A Sociological Analysis of Tacit Knowledge in Railway Maintenance Systems

An examination of the social construction of rolling contact fatigue of rail, with an analysis of the impact of organisational structure, culture and change on the development and utilisation of codified and tacit knowledge required for rail maintenance decision-making.

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DECLARATION

I, Aaron J. Wilson, declare the work within this thesis as my own.

Signed:

ACKNOWLEDGEMENTS

I thank my two supervisors, Prof. Donald MacKenzie and Dr Felix Schmid for their guidance, thoughts, and outstanding support during the entire project. I would also like to thank Dr. Jan Webb for her comments on earlier work. I thank also fellow students and staff of the School of Social and Political Studies at the University of Edinburgh for providing constructive comments throughout the research period.

For my research I required extensive contact with the railway industries of Britain and Switzerland. Due to the nature of my project, and as will become evident, I kept the identity of all workers I met, interviewed, and observed at work, hidden. The cooperation of all these railway industry workers (from maintainers such as trackmen, ultrasonic operators, welders and rail grinders to metallurgists, technicians and scientists) was absolutely essential if my project was to work at all – the help and support I received from all the workers was exceptional and my project only gained from their collaboration: my thanks go to all those who participated in my research. There are, however, three industry workers I want to thank individually. To gain access to the railway environment and to conduct my fieldwork in Britain, I had to gain the relevant safety certificate. My thanks go to the person who enabled this to happen. My actual fieldwork in Britain was coordinated and planned by another – again I thank him for his cooperation. Likewise in Switzerland I would like to thank the staff-member who planned and arranged my research needs – with the extensive assistance of these three people, the project as I envisioned it was fulfilled: thank you.

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ABSTRACT

The railway industry is largely neglected by current sociology, yet promising topics for sociological investigation abound: the organisational structure of the railway industry; risk management and the reaction to railway accidents in a “risk society”; the development and introduction of new railway technologies; the problem of railway project management, and so on. Despite this there is almost no “railway sociology” in Britain, a striking omission both in itself and in comparison with the wealth of work produced by the railway historian.

“Railway maintenance”, with an emphasis on the management of a technical problem called rolling contact fatigue (RCF), was chosen to be analysed in a sociological sense using sociological methods. RCF is the term given to cracking and flaking of metal of the rail surface which, it is generally thought, are faults that are generated from the stresses at the wheel and rail contact patch. It was also decided that the role of tacit knowledge in rail maintenance procedures would be examined. Tacit knowledge is acquired from experience and cannot be explicitly formulated. This means it cannot be effectively transmitted by impersonal means as it often requires person-to-person interaction. Nevertheless, tacit knowledge is a critical part of railway maintenance.

The project was conceived in the aftermath of the fatal accident at Welham Curve near Hatfield, England in October, 2000. Though caused by RCF, non-technical issues connected to the organisational culture of the industry were of direct consequence: How leaders of an organisation perceive its objectives, and how employee tasks and specialisms are structured have a huge impact on how workers conduct their work. These matters intertwine as workplace cultures develop, become embedded, and affect a group’s worldview and language codes, which in turn, impact on inter-organisational communication and interaction. At all levels in an organisation therefore, decision-making is effectively a product of the environment within which it is conducted. The effect this has on technical decision-making which requires tacit knowledge is substantial.

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GLOSSARY

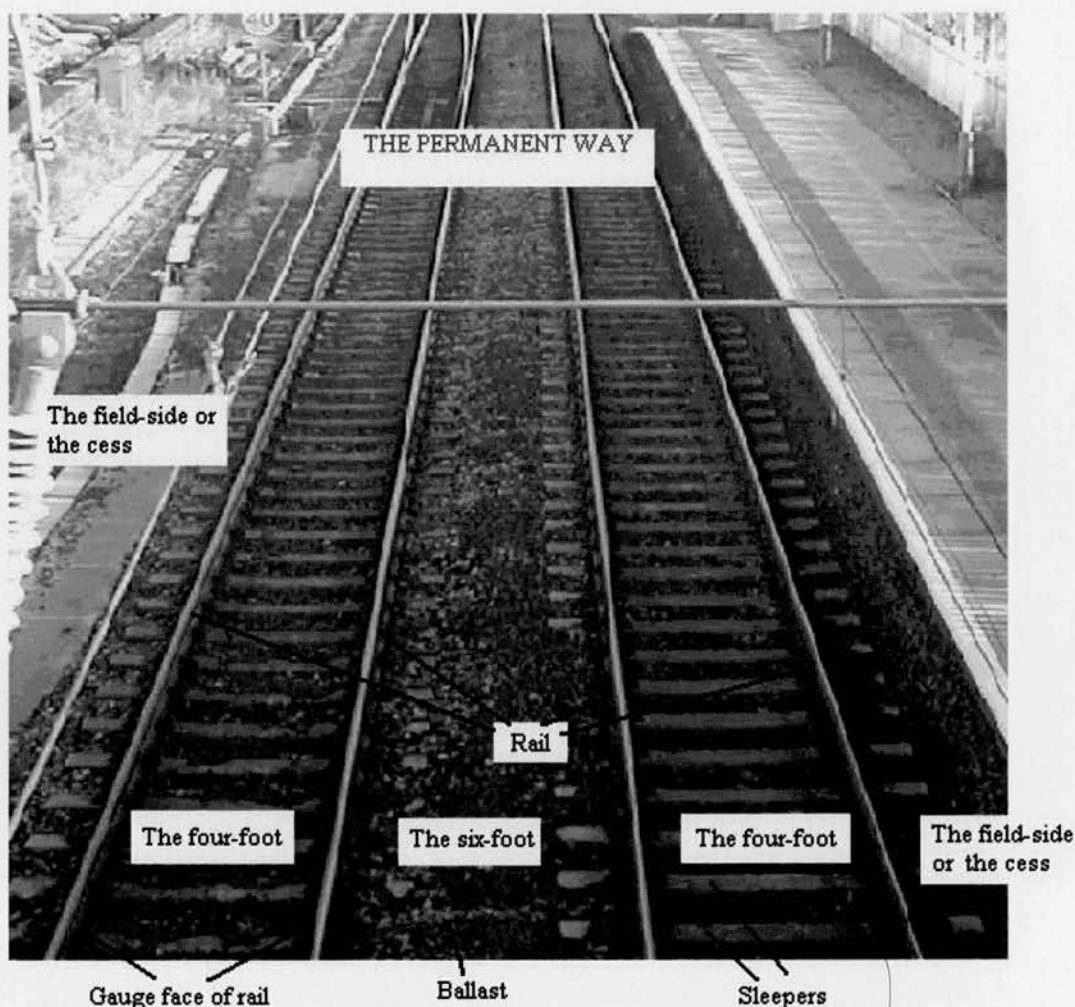


Figure 1 Terms of the Permanent Way (source: author's photograph).

64 stone grinding unit:

Rail-based vehicle with 64 rotating grinding stones attached to its underside to grind the rail surface to a uniform shape. Removes shallow cracking. Often referred to as “The Speno” after the name of the company that manufactured it.

91/440/EC:

The European Community Directive that required of community members to separate in accounting terms traffic operation from infrastructure ownership, maintenance and renewal costs.

Ballast:

Part of the infrastructure and component of the permanent way. Refers to the stones within which the sleepers are embedded (see fig. 1).

British Rail:

The nationally owned operator of the British railway network between 1947 and 1994.

Cant of railway track (and cant deficiency):

The relative position of rails on a curve: the outer rail is set higher than the inner rail to ease the passage of traffic and to minimise contact between wheel flange and rail. Cant deficiency and cant excess refers respectively to a situation where a train traverses the curve at a speed greater than the so-called “balancing speed.”

Cess side:

That area of the permanent way that separates the “near-side rail” from boundary fences, embankments, etc. Is often like a small ditch that track workers walk in when going to a site. Re: walking in the cess (see field side) – (see fig. 1).

Chair:

Part of the infrastructure and component of the permanent way. What the rail sits in, and which is connected to the sleeper.

Clips:

Part of the infrastructure and component of the permanent way. Components that secures the rail to the chair.

Contact Patch:

The area where the wheel and rail touch and which transmits the load as well as traction and braking forces.

COSS:

Controller of Site Safety. Individual charged with ensuring safety rules are adhered to during work at a possession.

Cracking:

Fault or defect whereby a series of cracks have appeared on a rail.

CWR:

Continuously welded rail. Where lengths of rail have been welded together (via a thermite weld) to give the effect of one long continuous rail. Where rails are not connected by means of fishplates.

Defect:

Used interchangeably with "Fault". Refers to internal or surface problems such as cracks, tache ovals, squats, fatigue, RCF, wear.

De-lipper:

Grinding machine use to remove lipping from the rail's field side corner or gauge corner.

Fault:

Used interchangeably with "defect". See defect.

False flange damage:

The process where the running tread of the wheel of a locomotive, wagon or carriage, has worn to a level where it exhibits the effect of a "false" flange. The false flange causes damage to the rail surface, most notably at switches and crossings as traffic moves from one line to another.

Field flow:

Similar to lipping. Where the rail's surface metal has been pushed by the passage of traffic to the field side (or cess-side, see fig. 1) of the rail. Causes lipping.

Field side:

See Cess-side (see fig. 1).

Fishplate:

The pair of metal plates that connects two lengths of rail and which are bolted to the web of the rails.

Flaking:

See RCF.

Flange:

Raised part of the wheel that guides vehicles along the rail.

Foot:

Part of the rail that sits in the chair which is connected to the sleeper.

Four foot:

Section of the permanent way between the two running rails (see fig. 1).

Friction:

Refers to the process that exists where two surfaces are in repetitive contact, e.g., wheel and rail.

Gauge corner:

Top corner of the rail head that faces into the four foot. Opposite to the field corner (see fig. 1).

Gauge corner cracking:

Subset of Rolling Contact Fatigue phenomenon. Describes a series of cracks that occur on the gauge corner.

Green zone working:

When traffic is not operating on a section of railway and work on the permanent way can be undertaken without the aid of a look-out.

Grinder:

Typically refers to the machinery used by individuals to grind the rail to remove shallow cracking from the rail surface.

Head checking:

Subset of Rolling Contact Fatigue. Describes a series of cracks that occur on the rail head between the gauge corner and field corner.

Infrastructure:

Refers to the whole assemblage of the railway environment: the permanent way, over head electrical constructs, signalling, stations, bridges, etc.

Infrastructure Maintenance Company (IMCs):

Private companies that won contracts for the maintenance of different parts of the British railway network. Since Network Rail took over Railtrack the IMCs have been taken in-house and their workers now work for Network Rail.

Line:

The term given to a track when referring to destinations on the track, i.e., Edinburgh – Glasgow line.

Lipping:

See field flow. Where metal movement has create a jagged lip on either gauge corner or field corner.

Lookout:

Individual whose purpose is to look-out out for traffic and to warn others whilst work is done on the permanent way: Required for red-zone working.

NDT:

Non-Destructive Testing. Where the component to be tested is not destroyed during examination. Ultrasonic inspection is a form of non-destructive testing.

Network Rail:

The not-for-profit organisation that took over Railtrack and became infrastructure controller of the British railway network in October 2002.

Pads:

Part of the infrastructure and component of the permanent way. A pad sits between the rail foot and chair, or in some cases, the sleeper.

Permanent way:

The term given to the whole railway track: i.e., pads, rails, clips, chairs, sleepers and ballast (see fig. 1).

PICOP:

Person In Charge Of Possession. Individual in charge of organisation of work during a possession. Tells workers when work can start and when it finishes.

Plain rail:

Length of rail that is not part of switches and crossings.

Possession:

Term given to the period of time when work can take place on the permanent way, from the expression “the engineer takes possession of the line”

Privatisation:

Refers to the process of implementing the EU directive 91/440 in Britain’s railway industry once British Rail was sold to the private sector in 1994.

PTS:

Personal Track Safety. The safety certificate that every person who needs access to the permanent way must have before entering.

PWSI4:

Permanent Way Special Instruction 4. The instruction specifically produced for the management of Rolling Contact Fatigue.

Rail:

Component of the infrastructure and part of the permanent way: The long piece of metal upon which the train's wheels travels (see fig. 1).

Rail grinding:

The process of removing a layer of metal from the rail's surface to remove shallow cracking or to adjust the rail head profile.

Rail head:

Where the wheel is in contact with the rail. Where RCF and other faults occur, such as lipping.

Railtrack:

The private company which operated and owned the British railway network after privatisation. Was acquired out of railway administration by Network Rail in 2002.

Railway:

Refers to the permanent way (see fig. 1).

RCF:

Rolling Contact Fatigue. Term which covers the subsets of cracking and flaking of metal known as gauge corner cracking, field flow, squats, and head checking. Generally thought to be a fault that is generated by the stresses existing at the wheel / rail interface.

Red zone:

Where work is conducted on the permanent way whilst traffic is allowed to pass. Requires a look-out.

Roller Search Unit (RSU):

See "The Sperry".

Running band:

That area of the railhead surface where the wheel travels. Typically identified by a long narrow strip of shiny and worn rail.

SBB:

Schweizerische Bundesbahnen or Swiss Federal Railways. The owner and operator of most of Switzerland's standard gauge railway network.

Shelling:

See RCF. Term given to the flaking of metal from the rail's surface.

Six foot:

That area of the railway track between separate, parallel lines (see fig. 1).

Sleeper:

Part of the infrastructure and component of the permanent way. Is embedded in ballast and supports rails (see fig. 1).

Squats:

Form of rolling contact fatigue. Often looks like a bruise just below the surface of the rail where head checking occurs. Often cracks and flakes.

Stock rail:

Part of the infrastructure and component of the permanent way. Is part of a switch and crossing (S&C). The rail that is continuous throughout an S&C – does not “switch” – see switch blade.

Switch and crossing (S&C):

Part of the infrastructure and component of the permanent way. Is that area where traffic can pass from one line to another. See Line.

Switch blade:

Part of the infrastructure and component of the permanent way. It is the rail that moves, allowing traffic to move from one line to another.

Tâche ovale:

Internal rail defect that is thought to be caused by non-metallic and hydrogen inclusions.

The Cess:

See Cess side (see fig. 1).

The Speno:

See 64 stone grinding unit

The Sperry:

Ultrasonic testing technique where equipment is fixed to a basic carriage that is pushed along the rail by hand. Named after the company that manufactured the device. Also known as the Roller Search Unit.

Train Operating Company (TOC):

Refers to companies that lease rolling stock and have a franchise to operate passenger train services.

Ultrasonic Inspection:

A non-destructive testing technique (see NDT) often used by technicians to assess the internal quality of the rail.

UTU:

Ultrasonic Testing Unit. Rail based vehicle with ultrasonic testing equipment fixed to its underside.

UTU2:

Advanced version of the UTU.

Visual Inspection:

Maintenance activity where individuals inspect the permanent way looking for faults.

Walking stick:

Term given to the ultrasonic testing equipment. Also known as the Sperry and the RSU.

Wear:

Refers to the deformation of the rail due to repeated contact with the wheel.

Web:

Thin middle section of the rail between the foot and the head.

Wheel / rail interface:

Refers to the meeting point of the wheel and the rail. See contact patch.

Wheel burns:

Refers to the process and resulting deformation of the rail, due to the wheels of vehicles spinning and slipping on the rail whilst the vehicle remains stationary.

WRISA:

Wheel / Rail Interface Systems Authority. The railway industry body that was made up of different organisations within the industry who have an interest in developing knowledge about the wheel / rail interface. WRISA had to be disbanded for insurance reasons.

A NOTE ON THE FIGURES

All figures are author's own photography, sketch or diagram except for the following:

FIGURE 2-1 FATALITY TRENDS FROM 1975 – 2004 INTERNET SOURCE: HEALTH AND SAFETY EXECUTIVE WEBSITE: 13TH JUNE, 2005).

FIGURE 4-1 THE FLANGE AND RAIL HEAD RELATIONSHIP (SOURCE: JACK, 2001: 36).

FIGURE 4-2 TREVITHICK'S CATCH-ME-WHO-CAN (INTERNET SOURCE: WWW.SPARTACUS.SCHOOLNET.COM).

FIGURE 4-3 RESIDUAL STRESS DEVELOPMENT (SOURCE: RAILTRACK, 2001A:12).

FIGURE 4-4 RESIDUAL STRESS DEVELOPMENT. CURRENT THOUGHTS ON METAL MOVEMENT OF RAIL (SOURCE: RAILTRACK, 2001A: 12).

FIGURE 4-5 LONG-TERM TREND OF BROKEN AND DEFECTIVE RAIL REMOVED FROM BRITISH NETWORK (SOURCE: TTCI, 2000: A-9).

FIGURE 4-6 SYSTEM DIAGRAM FOR WHEEL / RAIL INTERFACE VARIABLES (SOURCE: BRETNALL, 1998).

FIGURE 5-3 DENOTING WHERE RCF SUBTYPES OCCUR ON THE RAIL HEAD (SOURCE: RAILTRACK, 2001E).

FIGURE 6-1 VISUAL INSPECTION FREQUENCIES (SOURCE: RAILTRACK, 2001C).

FIGURE 6-2 CRACK MEASUREMENT PROCEDURE (SOURCE: RAILTRACK, 2002).

FIGURE 6-3 CRACK SEVERITY CATEGORISATION (SOURCE: RAILTRACK, 2002).

FIGURE 6-4 RESPONSE TO CRACK CATEGORISATION (SOURCE: RAILTRACK, 2002).

FIGURE 6-8 TWO VISUAL INSPECTORS AT A SWITCH AND CROSSING (INTERNET SOURCE: WWW.ALVEYANDTOWERS.COM).

FIGURE 7-3; PHOTOGRAPH. INTERNET SOURCE: WWW.ALVEYANDTOWERS.COM.

FIGURE 7-13 STAR CRACKING SOURCE: (RT/CE/S/055, RAILTRACK, 1998B).

FIGURE 7-18 AN EXAMPLE OF SOME UT FORMULAE FROM THE PCN COURSES BOOKS (SOURCE: SERCO, 2002B: 'ULTRASONIC TESTING OF RAIL LEVEL 1 PART 2A SECTOR SPECIFIC THEORY').

FIGURE 7-19 ANOTHER EXAMPLE OF UT FORMULAE (SOURCE: 'SERCO, 2002B. ULTRASONIC TESTING OF RAIL LEVEL 1 PART 2A SECTOR SPECIFIC THEORY').

Figure 9-6 SBB Maintenance management process (source: Pfarrer, 2002: Conference paper).

"You remember how you and I dug the old railroad men we saw all over the country last winter? – We saw them with their lunch pails in the night in Baltimore and Carolina and Texas and Bakersfield. We dug them as workmen, we understood something about them."

Jack Kerouac (in a letter to his friend, Neal Cassady¹)

¹ In Charters, 1995.

1 INTRODUCTION AND LITERATURE REVIEW

1.1 INTRODUCTION

1.1.1 The topic of the thesis

This thesis documents an ethnographic investigation of the role of tacit knowledge in systems associated with rail maintenance, with an emphasis on the decision-making process involved with the management of rolling contact fatigue (RCF): the collective term for the subtypes of cracking that appear on the surface of the steel rail. The majority of the research was based in Britain, but for comparative purposes I also conducted a more limited ethnographic investigation of rail maintenance in Switzerland.

The thesis addresses several questions connected to the management and organisation of knowledge required for rail maintenance systems: what is organisational culture? How does it develop historically? How does it shape current work strategies? How do organisational leaders communicate risk management strategies to geographically dispersed workers? What role is there for procedural rules and what are the limitations: how do workers interpret them? The research found that much work is done in groups: decision-making is often a group activity which has an impact on the individual's learning processes. The thesis examines how groups develop, organise and utilise knowledge and skills, noting the vital role of mutual understandings, non-verbal communication, and tacit knowledge.

A major finding shows how the disruption of embedded cultural norms through organisational change (privatisation) had a major and lasting effect on rail maintenance activities. Perhaps more important though, are findings on tacit knowledge. Tacit knowledge cannot be captured in written instructions, yet it is indispensable if current best practice techniques are to be used. My findings explain how tacit knowledge is: collectively and socially developed; individually deployed; collaboratively utilised by the groups; and transmitted to individuals.

1.1.2 The timing of the research activities

The core findings come from interviews and observations which were conducted between October 2000 and June 2004. My research came at a particularly significant and turbulent time for the British railway industry as a whole. Unfortunately the series of serious rail disasters prior to the research period did not relent during it. The place names of Southall 1997, Ladbroke Grove 1999, and Hatfield 2000 were joined by Selby 2001, and Potters Bar 2002. 2004 was also a difficult year for the industry: four railway maintenance workers were killed in the North West of England, and at the end of the year three incidents occurred in as many weeks at level crossings – the worst of which took seven lives. Of these serious rail incidents however, it is the catastrophes at Hatfield and Potters Bar that have been the catalyst for several major changes that altered the organisational structure of the industry during the time of research.

Contract renewal negotiations between Railtrack (The British railway network owner and operator) and the private company (Balfour Beatty) that had the right to work on the line at Hatfield were on-going at the time of the crash; shortly after the disaster it was decided not to renew the contract (this information came from interviewee: 35). Some Balfour Beatty employees (and some Railtrack employees) have been charged with manslaughter in connection with the derailment – the case is being heard now, at the time of writing (spring 2005). Several media reports and government figures also pointed out the spiralling costs of railway maintenance in Britain in recent years. After Railtrack was given £1.5 billion in April 2001 from the government, and then asked for a further £4.2 billion just four months later (which was likely to push its overall debt to £17 billion²) the company was placed in administration in October that year. Then, several months later, in May 2002, the industry was rocked by yet another

² The Financial Times (30/01/03).

catastrophe. Two coaches of a passenger service left the rails after travelling over a switch and crossing³ at Potters Bar railway station, England. Several lives were lost as carriages charged into the station's platforms.

This series of events had a huge impact on Railtrack: numerous questions were raised about the company's ability to operate and maintain the network. In the end, and just four months after the Potters Bar disaster, it was announced that Network Rail, a not-for-profit and public-interest company⁴, would take over Railtrack (Network Rail officially started operating in October 2002). The company soon announced its intention of bringing railway maintenance back "in-house" and under the stewardship of the company. This objective was achieved within 12 months:

Network Rail today announces that it is to bring rail maintenance activity back in-house. The contracts currently held by the seven Infrastructure Maintenance Contractors [IMC] will be transferred to the 'not for dividend' company, unifying the operation and maintenance of rail infrastructure (Internet source: Network Rail website, 24th October, 2003)⁵.

I draw attention to these events and the impact they had upon the organisation of the industry as these changes occurred during the time I conducted my research. Much of the research occurred when the Hatfield derailment was still fresh in the memory - making the subject of railway maintenance a particularly sensitive issue⁶. This was the context within which I made my observations and it was during this time that I spoke to all my interviewees.

³ A switch and crossing is that section of track where two lines are joined.

⁴ Financial Times 30/01/03.

⁵ As one outcome of a more "hands-on" approach to railway maintenance (compared to Railtrack - see chapter three page 100), Network Rail has created a new apprenticeship training scheme which is based in Portsmouth.

⁶ In the methodology chapter (chapter two) I point out that some interviewees preferred not to be recorded - the climate I describe is perhaps why this was so. Additionally in chapter three I describe some of the hurdles I had to cross to gain access to the industry - being an outsider, as I was, gaining access was at first difficult. I, for instance, could have been looking to add to the "controversy" that has been surrounding the industry recently.

Though (as noted above) Network Rail started operating in October 2002, there was a lengthy transitional period where workers moved from private infrastructure maintenance companies (IMCs) to Network Rail. Due to this drawn out process workers often referred to Network Rail or Railtrack or IMCs indiscriminately.

1.2 THE STRUCTURE OF THE THESIS

To give the reader a sense of the structure of the thesis, it is better to review the chapters thematically rather than in the order in which they appear.

1.2.1 Chapter two and ten: A note on the research methodology and the conclusion

Prior to interviewing (office-based) senior engineers of rail maintenance companies, (laboratory-based) rail technicians and metallurgists, and prior to observing the physical work of “frontline” track workers, I had to learn about the industry. I familiarised myself with the different organisations involved with railway maintenance. I found out what the core activities of rail maintenance were and I developed a basic understanding of some of the associated technical terms and technical problems, such as RCF. This level of understanding gave me the ability to converse with workers and, as I conducted more interviews my knowledge developed. As research opportunities opened up I was given the chance to observe railway workers at work. It may also be worthwhile to point out that virtually all respondents (bar one), and all workers I observed at work, were male. Indeed, I found that the industry was male-dominated: during my research in Switzerland I spoke to just one female worker compared to none in Britain, whilst in Britain, out of the many conference presentations I heard, just two were presented by females.

The focus of the study has been on a particular aspect of railway maintenance, namely the task required to keep the surface and interior of the rail steel section in a state that is safe and fit for purpose. Routine rail maintenance requires three core competencies:

visual inspection, ultrasonic inspection, and rail grinding. Tacit knowledge underpins efficient visual inspection for surface rail cracks; ultrasonic inspection for internal rail flaws; and manual rail-grinding and profiling for the removal of surface cracks and managing rail deformity respectively. The data illustrates how workplace culture and bureaucratic *proceduralism* impact on and accommodate the tacit knowledge required for rail maintenance.

1.2.2 Chapters six, seven, and eight

Visual inspection, ultrasonic inspection, and rail-grinding usually occur in that order: a fault is found (visually), it is tested (ultrasonically) and, if indications suggest it, it is then removed or treated (ground). The importance of each activity and an account of the tacit knowledge required, demand a chapter in each case. These three activities, and the role of tacit knowledge, are detailed in chapters six, seven, and eight respectively.

1.2.3 Chapter five

In chapter five, we see how these maintenance activities are structurally organised and coordinated. I outline how a particular infrastructure maintenance company is structured and how it interacts with other companies, such as Railtrack and train operating companies. This chapter describes how rail maintenance knowledge is communicated between companies, how it is moved around and managed, and how it is developed. How risks with rail faults (namely RCF) are perceived, researched, and judged by technicians and senior engineers is also discussed, giving an insight into the thought-processes that suggest how rail maintenance should actually be physically executed. We also see quite clearly how these thoughts are transmitted to the frontline workers we meet in chapters six through eight.

1.2.4 Chapter three

Privatisation of Britain's railways in 1994, it is suggested by my findings, had a significant impact on the skills levels of the railway maintenance workforce. Many experienced workers, I was told, left the industry immediately post-privatisation, creating skill gaps in many aspects of rail maintenance in numerous areas around the British network.

The resulting inconsistencies gave me an insight into the role of history. Many of the workers I spoke to suggested that in those areas of the network where former British Rail (BR) workers remained, the quality of maintenance work was of a higher standard than those areas where "new" agency workers and contractors were common. After assessing their words it became obvious to me that a brief socio-historical account of rail maintenance should be completed. In chapter three, therefore, an illustration of BR's original rail maintenance organisation and methods is given. This is useful on a number of counts. It, for instance, points out the important role of culture and experience for learning processes and (tacit) knowledge development. More importantly however, we see how organisational change impacted on current rail maintenance procedures: by looking back in time we get a real sense as to why rail maintenance was carried out in the particular manner I observed.

1.2.5 Chapter nine

The majority of the thesis is centred on British rail maintenance processes. In chapter nine, however, we are given the chance to see how it is managed and physically executed in Switzerland. I analyse the maintenance activities of the Swiss railway operator: Schweizerische Bundesbahnen (SBB). I analyse the methods in the same way I analysed British methods: I describe the rail maintenance procedures that I saw on-site, and I describe the philosophies that underpin SBB's organisational structure. Attention is drawn to the similarities and differences that exist between the two national networks.

1.2.6 Chapter four

The reasons for differences in rail maintenance methods between Britain and SBB are symptomatic of a scientific / technological gap in knowledge concerning wheel / rail interface issues. Rail problems are due to interaction processes between the wheel and the rail which are exceedingly difficult to interpret and understand. Precise knowledge of how wheel and rail interact in all areas of a network does not exist. Nevertheless, the problems have to be managed. In his chapter I take a look at some current research. In doing so, we find out what the dominant thoughts are and how they shape current rail maintenance procedures.

Problems with the steel rail's fitness-for-purpose appeared as soon as a powered, rotating, travelling steel wheel was placed upon it. In this chapter, I also take a concise look at how rail problems emerged by looking back to a time two hundred years ago when the modern railway industry began to emerge.

1.2.7 Chapter one: the remainder of this chapter

This thesis is about the social, collective development of rail maintenance knowledge. It documents how this knowledge is organised and managed. Of interest therefore, is what others have said on the organisation and management of knowledge from a sociological perspective. What are the dominant thoughts regarding technological knowledge? – Where does it differ from science? How should complex technology be organised when there is a substantial risk of creating catastrophic outcomes? What is tacit knowledge and what does it mean for the technological organisation's training strategies, and what does it mean to the individual technical worker? What impact can organisational culture have on the management of technology? What is the relationship between risk management, decision-making, and context?

Social scientists have applied these questions, in part, to other environments such as nuclear power plants (Perrow, 1984) and space agencies (Vaughan, 1996). By

reviewing their findings, we will be in a position where we can intellectually scrutinise and understand to a greater extent the organisation of railway maintenance and rail maintenance in particular, and the implications that organisational forms, discussed later, can have. The remainder of this chapter provides an analytical framework for the rest of the thesis.

1.3 LITERATURE REVIEW

1.3.1 Introduction

Technology is a notoriously difficult term to define: how it interacts with, and differs from science could be the sole topic for an entire thesis. In this chapter, however, I slot this topic into one section (1.6, page 41). It is here we note one key similarity between the distinguishable subcultures of technology and science: both are shot through with uncertainty. Given technology's fickleness, we ask: *How should organisations manage complex technology?* This point is discussed through an account of the strengths and weaknesses of opposing organisational theories.

In section 1.7 (page 44) I argue that scientific and technological knowledge cannot be separated from society intellectually: the two are social constructs. The relationship between society and technology is analysed. We see how technology's historical development and construction is intrinsically related to the perspectives of relevant communities, and because technologies carry inherent risks, we ask questions about risk perception and its relationship with culture.

In an effort to tie the sections together and to add substance to what has been said, two case studies are examined. In doing so we find that technological management often requires tacit knowledge which typically cannot be worded in rules, regulations or procedures. This has profound implications for the organisation and for its individual workers and groups. I devote time to "group interaction"; in doing so we gain a *glimpse* of the tacit understandings shared among group members. In this section I

analyse the role of tacit knowledge from the perspective of the individual and the group: we see how it is generated and transmitted.

1.4 THE STRUCTURE OF ORGANISATIONS

1.4.1 Mechanistic bureaucracy / organic systems

Modern organisations are typically “bureaucratic”. Bureaucracy, Max Weber argued, was “the only way of coping with the administrative requirements of large-scale social systems” (Giddens, 1993: 287). Bureaucratic organisations aim to operate through clear rational systems which comprise of: (i) a high degree of specialisation and a clearly defined hierarchical division of labour, with tasks distributed as official duties with clearly circumscribed areas of command and responsibility; (ii) the establishment of a formal body of rules to govern the operation of the organisation; (iii) administration based on written documents; and (iv) impersonal relationships between organisational members and clients (Craib, 1997: 139 - 40).

This model has been described as “mechanistic” (Burns, 1969) and “Fordist” (Clegg, 1990: 179). In mechanistic and Fordist organisations “differentiation was the hallmark of the system. There was a maximal specialization of jobs and functions and an extensive differentiation of segmental roles” (Clegg, 1990: 179). These workplace groups or individuals deal with their specific tasks and problems. These groups are specialised and work only on their own affairs: they know what their responsibility *is* and what it *is not*. Boundaries of responsibilities and power are thus created, allowing the hierarchical management of the system to be displayed clearly on organisational flowcharts. This makes it feasible to plot the downward flow of instructions from chiefs to frontline workers, with production information returning in the opposite direction (Burns, 1969: 242 - 3). A mechanistic organisational form is not suited to organisations subject to internal stresses and strains (Merton, 1957: 196). It is untenable to apply mechanistic principles in an organisation subject to constant change:

Ideal bureaucracy falls short of realisation when rapid changes in some of the organisational tasks are required. ... When changes come along, organisations must alter their programmes; when such changes are frequent and rapid, the form of bureaucracy becomes so temporary that the efficiencies of bureaucracy cannot be realised (Perrow, 1972: 5).

To deal with this problem, Burns (1969) and Burns and Stalker (1961) posit *organic systems*. Organisations that adopt an organic system often have to adapt to unstable conditions, making it infeasible for individuals and groups to be hemmed into precise positions to deal with precise problems (Burns, 1969: 242 - 3). Organisations that operate through organic systems have been linked with ideas on flexible specialization theory (Tomaneny, 1994: 161), postmodern organisations (Clegg, 1990: 180), and post-Fordism (Grint, 1998: 285). In these organisational systems there tends to be less surveillance and supervision of workers, meaning there is more decentralised forms of workplace activity and control. Clegg (1990) introduces us to this topic: "Postmodernism points to a more organic, less differentiated enclave of organization than those dominated by the bureaucratic designs of modernity" (Clegg, 1990: 181). This organisational design is seen to be more efficient because the nature of problems that tend to arise in manufacturing and technological industries are technically complex and can rarely be broken down into precise steps, as was characteristic of the Fordist assembly line (Grint, 1998: 285) or distributed among specialist roles of a clearly defined hierarchical workforce: "New technology also required a more flexible and probably, therefore, a more skilled workforce. ... Flexible technology with an inflexible workforce does not lead to flexible production" (Grint, 1998: 284).

In other words, operatives in such organisations must now complete their work with a firm understanding of what is occurring throughout the organisation. They must know how their affairs affect others. (Burns & Stalker, 1961: 6). Clegg (1990) explains the difference this way:

Where modernist organization and jobs were highly differentiated, demarcated and de-skilled, postmodernist organization and jobs are highly de-differentiated, de-demarcated,

and multi-skilled. Employment relations... increasingly give way to more complex and fragmentary relational forms, such as subcontracting and networking (Clegg, 1990: 181).

Jobs, therefore, tend to lose formal definitions and precise responsibilities and work methods tend to be redefined only after interaction with others, and, once an understanding of the task as whole is known (Burns & Stalker, 1961: 6). Indeed:

The sanctions which apply to the individual's conduct in his working role derive more from presumed community of interest with the rest of the working organization in the survival and growth of the firm, and less from a contractual relationship between himself and a non-personal corporation (Burns & Stalker, 1961: 121).

This work system requires interaction and communication to be lateral, not vertical. Instead of instructing workers, communication resembles "consultation rather than command... [and] consists of information and advice rather than instructions and decisions" (Burns & Stalker, 1961: 121)⁷.

Burns's idea of mechanistic and organic systems developed during research on British electronics firms. The firms were "equipped at the outset with working organizations designed in accordance with mechanistic principles" (1969: 243). Yet, in the face of change, where commitments grew larger and a new situation confronted the industry, some firms stuck to mechanistic principles: in response to novel conditions, the firms reinforced the formal structure (1969: 243).

⁷ A similar idea is the "Task Culture" Handy (1981). This culture is "extremely adaptable. ... [It] seeks to bring together the appropriate resources, the right people at the right level of the organisation, and to let them get on with it. ... Each group ideally contains within it all the decision-making power required" (1981: 182).

1.4.2 Pathological reactions

Why did the firms not change their organisation as technical and commercial circumstances changed? (Burns, 1969: 246). Burns proposes that the orthodox bureaucratic system had become so ingrained that it appeared to be *the* only possible mode of organisation. What is more, change or the enlargement of commitments of the organisation's affairs were seen as unlikely, or just not contemplated (Burns, 1969: 243 - 4). Next, he proposes that it was incredibly difficult to change the system because it was made up of people who had specific interests, and a disruption of the ingrained *way of things* might be at odds with these very concerns.

He is a member of a group or a section with sectional interests in conflict with those of other groups or sections, and he is also one individual among many to whom the position they occupy, relative to others, and their future security or betterment, are matters of deep concern (Burns, 1969: 246).

Burns's work is an extension of work he completed with Stalker (1961). The colleagues consolidated March and Simon's (1958) idea of the "sub-group". Sub-groups develop "sub-goals" which, when viewed in isolation, can be at odds with the goals of other groups in the same firm:

When the individual is involved in the bigger, more active, communication network required for faster technical and commercial change, he is more fully implicated as a person, more committed, more involved. ... As a result he is drawn more frequently and more closely into personal relationships with other members of the organisation (Burns & Stalker, 1961: 234).

This could inadvertently invoke departmental loyalty and interest in one's own career:

If one adopts the view that an increased rate of technical progress is healthy, or necessary, or desirable, then resistance is indeed pathological. But equally, to resist adapting an organisation and work-roles to the demands of rapid change is a measure of self-defence as a natural reaction (Burns & Stalker, 1961: 237).

Individuals can shape the working organisation according to their own conceptions of needs, and groups can create a system of conflicts by limiting *the other's* involvement

in each working occasion. In trying to attain their own goal, one group may directly or indirectly impede another group in reaching theirs. Organisations can create an “inevitable conflict of multiple goals” (Perrow, 1970: 59). It is no surprise therefore that, despite maintaining an ideal image of bureaucracy, there are informal codes of conduct where a hidden, or true, organisational reality exists⁸ (Jacobs, cited in Lofland & Lofland, 1995: 89).

1.4.3 Organisational culture

When organisations change, the change agents must take into account the current form of culture. Culture, in sociological terms, refers to the learned, shared way of life of individuals within a society (Giddens, 1993: 31); it refers to those ties such as language, custom, convention and norms (Abercrombie et al, 1984: 98) that bind individuals together. Group members come to realise that their activities and conventions are fastened firmly to a set of structured ideas (Cohen & Taylor, 1992: 38). Choice and action are intrinsically related to the context within which they are performed (Cohen, 1994: 69). From our viewpoint, culture refers to the rules through which a job is organised, the values and attitudes that match such organisation and the behaviours and justifications which follow from this (Mars, 1994: vi). By referring to the electronic firms studied by Burns we can guess there was an over reliance on such culturally based historical procedures. The ingrained working methodology had falsely presented to the captains of that industry not what their organisation’s culture *is*, but what *it should be* (Grint, 1998: 126), and thus: “many of the ills of organizations stem from imposing an inappropriate structure on a particular culture, or from expecting a particular culture to thrive in an inappropriate climate” (Handy,

⁸ Testament to this are the numerous social studies of workplaces typically categorised as work-place deviance. The studies that have been completed by Ditton (1977); Mars (1994) are particularly brilliant. Other studies include Henry (1987); Burawoy (1979); Gabriel (1988); Punch (1996); and Carson (1977). All illustrate working organisations whose employees do not lend themselves to the ideal notion of workplace bureaucracy.

1981: 177). The upshot is clear: “if organisations are to remain effective, they must change, and change must be by design and not by default” (Newman, 1973: xii).

1.4.4 Bounded rationality

Nevertheless, “even when technical experts have time to discuss and plan around signals of potential danger their interpretations could be subject to numerous issues from a wider system that include competition, scarcity, bureaucratic procedures, power, rules and norms, hierarchy, culture and history” (Vaughan, 1996: 415). Such issues can shape “managerial behaviour that is not always, or even usually, rational” (Wright, 1994: 80). This is why: the issues listed by Vaughan, “form institutional arrangements [which] constrain individual behaviour by rendering some choices unviable, precluding particular courses of action” (DiMaggio & Powell cited in Vaughan, 1996: 37). Burns (1969) deepens our understanding of this point when he says: “On taking a job, the organisation’s [worker] steps into a cognitive framework and accepts a set of constraints on purposive action which are consonant with those of the organisation” (Burns, 1969: 238 - 9). Decision-making is thus constrained, making optimisation infeasible. Instead of being an example of perfect rationality, decision-making is typically completed within a sphere of “bounded rationality” (Simon, cited in Vaughan, 1996: 36; Wright, 1994: 92); the decision-making performance is therefore more to do with “satisficing” (Simon, cited in Vaughan, 1996: 36), rather than optimising. Therefore, to “understand decision-making in any organisation, we must look at individual action within its layered context” (Vaughan, 1996: 37).

1.4.5 The layered context

James Reason says that organisations, today, after an industrial calamity, are unlikely: “to end their search for the cause ... with the mere identification of ‘sharp-end’ human failures: Such unsafe acts are now seen more as a consequence than as a principal cause” (Reason, 1997: 10). Reason’s point ties in with Hutter’s (2001). Her railway industry-based research suggested that although accidents stemmed from organisational bases, workers intriguingly “regarded [accidents] as unique [and]

explained [them] in terms of individual carelessness or luck rather than systemic or structural reasons” (2001: 298).

Though humans are naturally fallible and prone to error and procedure violation, Reason (1997) points out that accidents in complex organisations often find their source(s) beyond the scope of individual psychology. Reason calls these sources “latent conditions” (1997: 10). These inevitable conditions exist because:

Resources are rarely distributed equally between an organisation’s various departments. The original decision on how to allocate them may have been based on sound commercial arguments, but all such inequities create quality, reliability or safety problems for someone somewhere in the system at a later point. No single group of senior managers can foresee all the future ramifications of their current decisions (Reason, 1997: 11 - 12).

It seems therefore, that regardless of how the worker approaches his or her work (as a deviant, or pathologically, or well intended), modern business and technological organisational systems are inherently imperfect (Albrow, 1970: 90).

1.5 ORGANISATIONAL THEORIES

1.5.1 High Reliability Theory

Numerous organisations today operate increasingly complex technologies which contain a high potential for catastrophe. Therefore, how workers interact to form a work-place system to control technology is critical. In 1984 the Berkeley School of high reliability theorists started a project which, among others, examined the organisational set-up of a nuclear power plant and an air traffic control organisation. They were chosen because they had “excellent records of safety” (Roberts, 1993: 2 & 17) despite operating risky technologies.

The organizations were designed to account for expected and unexpected contingencies. Their design rendered them adaptive and sensitive to changes within

and out-with the organisation (Roberts, 1993: 19). Indeed, common characteristics were typically found: An *ab initio* assumption that errors are omnipresent and insidious and that eternal vigilance is the price of success; a parallel assumption that the sources of error are dynamic, not static. Therefore, monitoring mechanisms must be constantly re-invigorated; maintenance of redundant modes of problem solving at the operational level, and resistance to pressure to resolve or 'rationalise' the process by adopting a single 'best' way approach; the creation, maintenance and exercise of multiple simultaneous informal organisational structures adapted to contingencies (structural variation according to the nature of the problem); a particular kind of obeisance to formal regulations and codes (going by the book) extended with accepted standard operating procedures based on tradition (Roberts, 1993: 23). The organisations took the initiative in meeting and steering change (Newman, 1973: xv).

The findings suggest that serious accidents with hazardous technologies are not inevitable, but *can* be prevented through intelligent design and management (Sagan, 1993: 15). There is a belief that rationally organised complex organizations can compensate for well-known human frailties (Sagan, 1993: 16).

1.5.2 Creating a culture of reliability: the tacit mechanisms of socialisation and internalisation

Reliability does not occur by simply putting in place the structures. A reliability culture needs to be created, but:

How can an organization ensure that lower level personnel will identify situations properly, behave responsibly and take appropriate actions? (Sagan, 1993: 23).

Successful socialisation into the reliability culture assigns the recruit with the authority, experience and the technical know-how to respond to the problem at hand sufficiently. Reliable decentralisation requires a centrally-controlled socialisation process (Sagan, 1993: 22), which presents to the recruit the methods and philosophies of the organisation which he or she should *internalise*. Internalisation refers to the

process whereby the individuals learn and accept social norms and approved conducts of their society. They are said to have internalized social norms when they act on them freely⁹ and obediently (see Berger & Luckmann, 1966: 183 - 193¹⁰).

Internalisation is, therefore, “the form of commitment most desired by organisations” (Handy, 1981: 132), for it creates a homogeneous set of assumptions and decision premises which, when they are invoked on a local and decentralized basis, preserve co-ordination and centralization (Sagan, 1993: 22 - 23): it is a commitment that is self-maintaining and independent of the original source of influence (Handy, 1981: 132). Kunda (1992) explains what internalisation means for a senior manager of a successful engineering company. The company’s organisational culture was held responsible for the success; it was described as “strong” (1992: 5), but “a way of life taken-for-granted” (1992: 3). Accordingly, Kunda asks: how did this form of working life come about?

The guys up there are independent and ambitious. ... That they are committed there is no doubt. But they are unmanageable. ... That formal structure tells you nothing. How then, he wonders, can he make them see the light? Work in the *company’s* interests? Cooperate? Stop, or at least channel the pissing contests? And not make him look bad? Dave [the manager] knows that whether he controls it or not, he owns it. ... His strategy is clear: Power plays don’t work. You can’t *make ’em* do anything. They have to *want* to. So you have to work through the culture. The idea is to educate people without them knowing it. Have the religion and not know how they ever got it! (Kunda, 1992: 4 - 5) (See figure 1-1).

⁹ When I say “freely” I am referring to how Kunda (1992) might refer to it in an example given soon and how Handy (1981) may use the term. He says: “Internalization also means that the individual recipient of influence adopts the idea, the change in attitude or the new behaviour, as his own. Fine. He will act on it without pressure. The change will be self-maintaining to a high degree. But he will also tend to believe that the change was his own idea and no one else’s. He will in a sense, deny that the influence took place” (1981: 132). See also Crane’s work as mentioned in Collins (1982: 47)

¹⁰ The key point however is this: “Socialization always takes place in the context of a specific social structure. ... Since every individual is confronted with essentially the same institutional programme for his life in society the total force of the institutional order is brought to bear with more or less equal weight on each individual, producing a massivity for the objectivity to be internalised. ... By successful socialisation we mean the establishment of a high degree of symmetry between objective and subjective reality” (Berger & Luckmann, 1966: 183 - 4).

From a more general perspective, Berger and Luckmann (1966) examine a similar issue as Kunda: they, for instance, ask, how does “a taken-for-granted “reality” congeal for the man in the street?” (1966: 15). To go about answering this question, the authors accept the “social relativity of knowledge and reality” (Berger and Luckmann, 1966: 15):

A sociology of knowledge will have to deal not only with the empirical variety of “knowledge” in human societies, but also with the processes by which *any* body of knowledge comes to be socially established *as* “reality” (Berger & Luckmann, 1966: 15).

They qualify this by then asking, how is this ‘reality’ “developed, transmitted, and maintained?” (1966: 15). Much of their work (1966) subsequently refers to a form of “learning”, through social activities and processes, which may be described as “tacit”:

The individual, however, is not born a member of society. He is born with a predisposition towards sociality, and he becomes a member of society. In the life of every individual, therefore, there is a temporal sequence, in the course of which he is inducted into participation in the social dialect. The beginning point of this process is internalization: the immediate apprehension or interpretation of an objective event as expressing meaning, that is, as a manifestation of another’s subjective processes which thereby becomes subjectively meaningful to myself (1966: 149).

We can link this somewhat cumbersome quote to another part of Berger and Luckmann’s thesis (1966) which, though dealing with the process of internalisation in a pragmatic sense, still points to an important role for tacit mechanisms and a form of mutual understanding which cannot be explicitly said or codified (i.e., is tacit):

In the complex form of internalization, I not only “understand” the other’s momentary subjective processes, I “understand” the world in which he lives, and that world becomes my own. This presupposes that he and I share time in a more than ephemeral way and a comprehensive perspective, which links sequences together inter-subjectively. We now not only understand each other’s definitions of shared situations, we define them reciprocally. A nexus of motivations is established between us and extends into the future. Most importantly, there is now an ongoing mutual identification between us (1966: 150).

Berger and Luckmann (1966) suggest that this state of affairs becomes “taken-for-granted ... As long as they are not challenged” (1966: 168). In other words, the taken-for-granted reality must be “maintained... The reality of everyday life is on-goingly reaffirmed in the individual’s interaction with others. Just as reality is originally maintained by social processes, so it is maintained in consciousness by social processes” (Berger and Luckmann, 1966: 168 - 9). This essentially means the development, transmission and maintenance of the taken-for-granted knowledge that underpins reality refers to those tacit mechanism outlined above: the successful socialisation of society members, in the sense that they will thus act freely and obediently, in the way Handy (1981: 131 – 2) suggests, requires an internalisation process which involves tacit and implicit social mechanisms.

Later (in section 1.9.2 page 56 and section 10.1, page 59) we analyse, to a significantly deeper level, the relationship between internalisation and how individuals acquire subject/role-specific tacit-knowledge whilst discussing language construction, secondary socialisation and distributed cognition.

For now however, (from the premise of a discussion on organisational theory) continual education is critical if the workplace member is to successfully internalise the workplace reality and the philosophies that underpin it. Continual education reinforces the organisational structure; sensitises the workers to implicit work-place necessities such as technical know-how; reinforces “codified” knowledge; and drives away the negative aspects of stability and routinisation. It constantly reinvigorates the nature of work for workers: it may produce a “self-regulating work unit where operators are empowered to directly address risks and uncertainties” (Sagan, 1993: 24 – 5, see also author’s sketch in fig. 1.1).

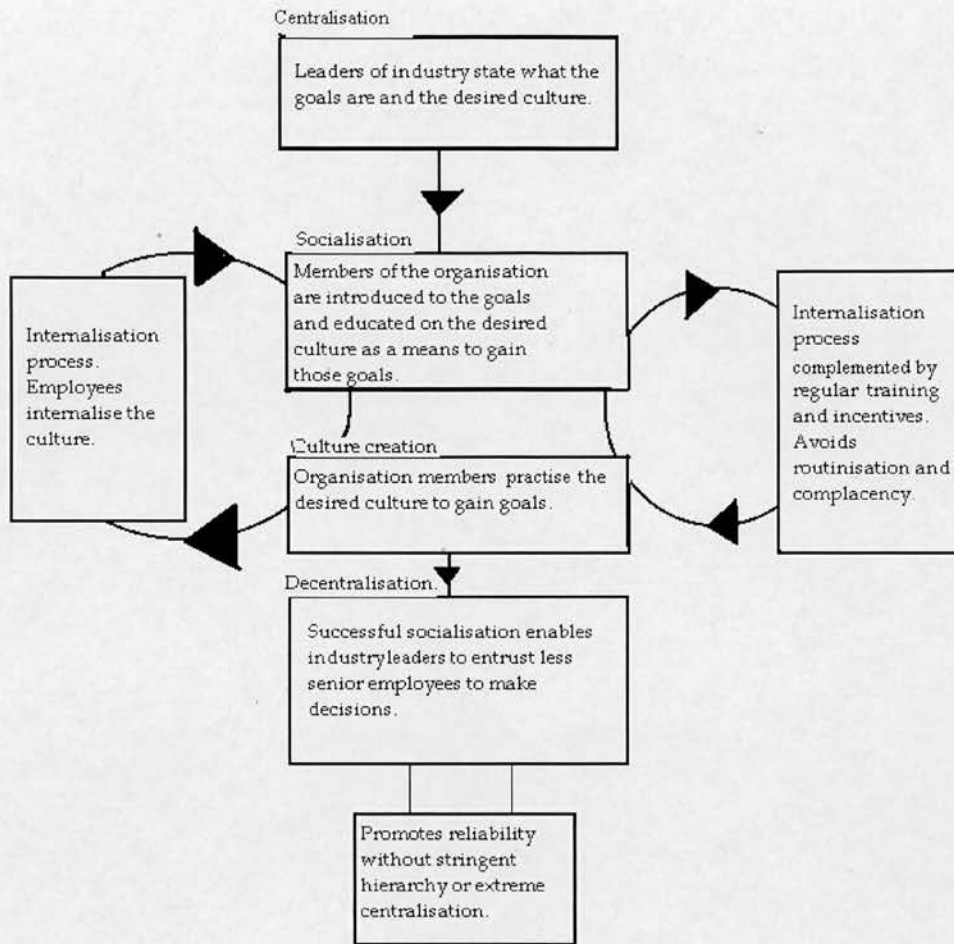


Figure 1-1 Creating a Culture of Reliability (author's own sketch).

1.5.3 Normal Accidents

The organisations in the Berkeley school project held records of safety which were a “puzzling paradox for the researchers; it seemed to be a negation of Charles Perrow’s findings” (Sanne, 1999: 23). Perrow claims that: “The characteristics of high-risk technologies suggest that no matter how effective conventional safety devices are, there is a form of accident that is inevitable” (1984: 3):

The argument is simple. We start with a plant, ship, biology laboratory, or other setting with a lot of components (parts, procedures, operators). Then we need two or more failures among components that interact in some unexpected way. No one dreamed that when *x* failed *y* would also be out of order and the two failures would interact so as to both start a fire and silence the fire alarm. Furthermore, no one can figure out the interaction at the time and thus know what to

do. The problem is just something that never occurred to the designers. Next time they will put in an extra alarm system and a fire suppresser, but who knows, that might just allow three more unexpected interactions among inevitable failures. This interacting tendency is a characteristic of a system, not of a part of an operator (Perrow, 1984: 4).

Highly complex technology is made up of many individual components, and as is often the case, their interaction is tightly coupled, meaning: “there is no slack or buffer or give between two items. What happens in one directly affects what happens in the other” (Perrow, 1984: 90). Subsequently, tightly coupled-interacting technology is capable of quickly generating unfamiliar, unexpected sequences that are not immediately comprehensible to the operators. Additionally, because the system is tightly coupled, there is little opportunity or slack for the operator to override any problems (Perrow, 1984: 333). Implementing apparatus to override potential problems will only aggravate the system further: “technological fixes only increase the interactive complexity and tighten the coupling” (Perrow, 1984: 333).

The significance of Perrow’s work is that it highlights a contradictory dilemma for organisations operating highly complex technologies with tightly coupled components. Mechanistic (Burns & Stalker, 1961) or centralised control is required to ensure operation of all tightly coupled components is systematic, precise, and punctual. Yet the nature of the highly complex technology requires operators to be able to take “independent, creative action” (Perrow, 1984: 10) when localised failures occur – an “organic” (Burns & Stalker, 1961) or decentralised mode of organisation is thus required. “But systems cannot be both decentralized and centralized at the same time; they are organizational Pushmepullyous, straight out of the Dr Doolittle stories, trying to go in opposite directions at once” (Perrow, 1984: 10). Organisational contradictions mean accidents are inevitable, thus normal.

The differences between Normal Accidents Theory and High Reliability Theory are clear. The former says that accidents are inevitable when there is a combination of

tight coupling and high complexity, and that structural arrangements to account for technical failure merely add to the chance of catastrophe. Others, however, believe accidents are a consequence of breakdowns in social processes and comprehension (Roberts and Weick, cited in Sanne, 1999: 24). Through explicit training that incorporates experience, judgement, intensive communication, and a capacity for flexible reorganisation in demanding situations, workers can detect and correct errors (Sanne, 1999: 24 - 5). Despite the differences, the theorists are fully aware of the need to socially engineer the structure of the organisation due to the capricious nature of technology. The argument is about how to deal with unruly technology.

1.6 SCIENCE AND TECHNOLOGY

1.6.1 The traditional hierarchical model

The idea that technology is unruly will be construed as surprising by some, particularly so if they accept the following definitions:

Engineering: *n* applying scientific principles to the design and construction of engines, cars, buildings, or machines.

Science: *n* systematic study and knowledge of natural or physical phenomena.

Technology: *n* application of practical or mechanical sciences to industry or commerce (Collins Dictionary, 1998).

Apparently engineers only utilise scientific findings for technological operation. This perspective has been described as the “traditional hierarchical model” (Barnes & Edge, 1982: 148). This model depicts technology as a “routine activity of working out and realizing the implications of scientific theories. [Technology] is a humdrum, uncreative activity crucially dependent upon basic science” (Barnes & Edge, 1982: 148). However, “engineers know from experience that this view is untrue” (Vincenti, 1990: 3). Correspondingly, socio-historic case studies of technological innovation have shown “that ... technologists possess their own distinct cultural resources, which

provide the principle basis for their innovative activity” (Barnes & Edge, 1982: 148).

The traditional model, it seems:

Ignores the many non-scientific decisions, both large and small, made by technologists as they design the world we inhabit. Many objects of daily use have clearly been influenced by science, but their form, dimensions, and appearance were determined by technologists – artisans, engineers, and inventors – using non-scientific modes of thought. Carving knives, bridges, clocks, and aircraft are as they are because over the years their designers and makers have established their shapes, styles, and textures (Ferguson, 1993: xi).

Accepting this argument means we possess “the basic elements of the modern understanding of the science / technology relation. This characterizes science and technology as distinguishable subcultures, each with their own bodies of lore and competence,” (Barnes & Edge, 1982: 150) which at times, interact (Vincenti, 1990: 4).

1.6.2 The symmetrical model

Barnes and Edge (1982) point out that: “technologists do, at times, make use of findings and theories of basic science... [and] it is equally the case that scientists make occasional use of the ideas and artefacts of technology (1982: 149); indeed, “think of the great dependence of science on the computer, without which some modern scientific specialities could scarcely come into existence” (MacKenzie & Wajcman, 1985: 9). This means the two clusters of disciplines can stand alone, equally or symmetrically (Barnes & Edge, 1982: 150).

Science and technology are presented in the symmetrical model as clearly demarcated subcultures that may interact. Yet in reality, boundaries between the two are unclear (MacKenzie & Wajcman, 1985: 3). When philosophers try to separate the two, they “tend to posit over-idealized distinctions” (Pinch & Bijker, 1984: 402). Nevertheless: “An interactive model remains relevant over a wide range of characterizations of science and technology: it is possible to disagree about what science and technology *consist in* and yet agree upon the form of their relationship” (Barnes & Edge, 1982: 152). To be sure, a clear-cut account of the interaction between the two is still to be

found: “When science seems less than sure, technology is cited in its defence, and when technology seems less than sure, science is summoned to the rescue; the responsibility is passed backward and forward like the proverbial hot potato” (Collins & Pinch, 1997: 4). What is more, technological and scientific innovation is often less than sure: it is often shot through with uncertainty (Schon, cited in Barnes & Edge, 1982: 150), and unruliness (Wynne, 1988).

1.6.3 Unruly technology

Wynne (1988) takes exception to the idea that “data generated by following scientific rules of method lead mechanically to regulatory and policy conclusions. [Rather], in reaching conclusions there is a great deal of interpretative negotiation behind the more formal language of precise and standard rule following” (Wynne, 1988: 148). Thus, a formal public image of technology as mechanical, rule following behaviour belies a far less clearly rule bound and determined world of real technological practices, (Wynne, 1988: 148). Barnes and Edge (1982) give a reason for this: “There may be disagreement or obscurity as to what precisely its ‘implications’ are. And those ‘implications’ may be disconfirmed by practice, so that the theory has to be reconsidered and new and different ‘implications’ ‘deduced’ from it (1982: 150). A technological hypothesis therefore, is never fully exposed:

Existing knowledge is always liable to prove insufficient: additional unexpected features invariably appear in every new artefact or material process, throwing new difficulties in the path of further advance.... Projects may set off on in one direction and end ‘successfully’ at an entirely unlooked for destination as a result of this kind of uncertainty (Barnes & Edge, 1982: 150).

In technological development it is unfeasible to predict universality with experiments. For applying a scientific hypothesis within technology, means the hypothesis would have to claim:

Regardless of social aspects the safe operation of design ‘y’ is exactly reproducible on future occasions, regardless of time and place, and:

That design 'x' is capable of intervention to pre-empt or limit knock-on effects of localised features (Wynne, 1988: 158).

Technological systems evolve “uncertainly according to innumerable *ad hoc* judgements and assumptions” (Wynne, 1988: 151): Technology does not fall in line with historical operating paradigms; instead it requires the existing paradigm to be manipulated or extended¹¹. This means that during technological evolution, relevant practices are recapitulated into an updated statement of formal rules, for example when new codes of practice are issued by a regulatory body (Wynne, 1988: 153). Invariably, the definition of failure and success is fluid and subject to incremental change, and of course, entirely dependent upon the community that decides “what similarities matter and what differences do not in technological testing” (MacKenzie, 1996b: 255).

1.7 SOCIETY AND TECHNOLOGY

1.7.1 The social construction of technology

Since all human activity takes place within society, all technology has society at its centre (Collins & Pinch, 1997: 5).

These words ring true after reading case studies of technological development. For instance, Pinch and Bijker's (1984) well-known historical study of the bicycle showed how certain cycles prevailed over others due to the impact of perceptions and interpretations of “relevant social groups”. Quite similarly, Robert Pool's (1997) text

¹¹ A full explanation regarding paradigm manipulation and exploitation is given when discussing Thomas Kuhn's work later, but just now we can say that a scientific paradigm is a method of work that scientists adhere to. The paradigm dictates what scientific work should be carried out and how; it suggests what hypotheses are deemed acceptable and worthwhile for instance.

on why nuclear power is the way it is, illustrates society's role in technological development:

As I dug into the story of nuclear power, seeking the forces that had shaped it, I discovered that the key lay not so much with scientists and engineers as with a host of non-technical influences. ... I learned, one must look past the technology to the broader "socio-technical system" - the social, political, economic, and institutional environments in which the technology develops and operates... Every time I investigated what I thought was a technical question - Why was light-water the dominant reactor choice? What break through led to the broad commercialisation of nuclear power in the 1960s? Is there a feasible solution to the problem of storing nuclear wastes? - I found the answers taking me beyond the realm of engineering. The line between the technical and the non-technical that at first seemed so clear slowly dissolved, and I came to see the development of nuclear power as collaboration between engineers and the larger society. And in that partnership, society's role proved to be surprisingly deep and complex (1997: 5 - 6).

As MacKenzie sums up: "technological knowledge is social through and through" (1990: 10).

1.7.2 The socio-technical system

The term *socio-technical system*, as used by Pool, was coined by the Tavistock theorists during their famous studies in the 1960s. They demonstrated that the kind of technology used has a major effect on workplace culture and structure (in Handy, 1981: 189); postulating that technical requirements of the organisation can be designed simultaneously with social organisation and needs of the workers, without losing technical efficiency (in Schmid et al, 1994: 81). This view seemingly counters the deficiencies of the social construction of technology theory. Hecht (1996) writes: "analysing the meanings given to technologies and risks *after* they are constructed offers one possible [research] direction. Examining the ways in which technological activity *continues* to be social, cultural, or political, even after technologies reach "closure" can enable us to draw critical connections between the artefacts, structures and practices of technological activity and broader social, cultural or political issues" (1996: 518 - 9). Thus, the "bicycle study" and others were criticized for their rather cavalier attitude towards users, in that they did not show how users could actively

modify stable technologies¹² (MacKay & Gillespie cited in Oudshoorn & Pinch, 2003: 3): “users and technology are too often viewed as separate objects” (Oudshoorn & Pinch, 2003: 2). The theory does not show the *radical indeterminacy* role of the user¹³ (Callon, 1999: 181).

Callon (1999), Latour (1984), and Law (1991) strongly reject the idea that the user, (or agent, or actor) is a passive consumer of technology. They develop the idea of the Tavistock theorists and speak of *co-constructionism* (Murdoch, 2001: 117) and the actor-network theory – which was “developed to analyse situations in which it is difficult to separate humans and non-humans, and in which actors have variable forms and competencies” (Callon, 1999: 183). In terms of scientific and technical knowledge, they argue that development is far removed from traditional ideas of objective science. Their assumption is that society and knowledge are not detached: “though science and technology develop in some measure apart from the rest of the world, they are neither detached nor fundamentally different in nature from other activities... The development of scientific knowledge and technical systems cannot be understood unless the simultaneous reconstruction of the social contexts of which they form a part is also studied” (Law, 1991: 20)¹⁴. Law (1991: 8) then tells us that: sociologists must talk about “the-social-and-the-technical all in one breath.”

¹² Oudshoorn and Pinch (2003: 1) give some examples where “stable” technologies have been used in other ways not necessarily thought of by the artefact’s designers and constructors. They point out, for instance, how chiming clocks were used as an introduction to a Pink Floyd record, and how aircraft on 9/11 were used as giant missiles. And later, we see that Johan Sanne (1999) noted how air traffic controllers manipulated artefacts, such as navigational charts, and extended their use beyond their intended scope.

¹³ But, as Callon also notes, the co-constructionist or actor-network theory perspective has been criticised for failing to give a “satisfactory theory of the actor which is allegedly endowed with either limitless power or deprived of any room for manoeuvre at all” (Callon, 1999: 181).

¹⁴ For an excellent example of such a research project which drew out “critical connections between artefacts, structures and practices of technological activity and broader social, cultural or political issues” see: Hecht (1996).

The socio-technical system theory illustrates a workplace situation characterised like a rich tapestry: everything interlocks to create the whole. Thus for the workplace to operate effectively during periods of alteration, relevant changes must be made accordingly throughout the system: optimisation of the social and technical systems must be done in tandem (Schmid et al, 1994: 79).

1.7.3 Technological determinism

Abundant social studies of technology urge the rejection of the traditional view of science-based technology as being independent of context. Instead it is suggested that technological knowledge is either context dependent (the social construction of technology) or is co-constructed (the socio-technical system's theory). Either way, the point remains: technological knowledge is "associated with matters of traditions, culture and experiences of the social groups involved" (MacKenzie, 1990: 9). For that reason, many argue for the rejection of the idea that technological development has internal, autonomous, deterministic characteristics (Mackenzie, 1990: 385).

They argue that the continual, predictable and inexorable tide of progress (MacKenzie, 1990: 385) only *looks* this way because it gained momentum (Hughes, 1980: 15). By misreading *progress*, the general - but flawed - idea of technological development and change as being naturally cumulative is given. However it is better to view development as a "perpetual accretion of little details... probably having neither beginning, completion nor definable limits" (MacKenzie & Wajcman, 1985: 10) and crucially, such "perpetual accretion" can be mistaken for technological determinism.

1.7.4 Technological lock-in

Technological determinism fails to account for many "non-technical issues" that shape development whilst *Technological lock-in* (Arthur, 1999) tries to account for society's role. This theory considers the idea that technologies which are initially in

competition with each other and which have positive returns to adoption, either become adopted (with a chance of cornering the market) or are frozen out due to seemingly insignificant *chance* events. Now the technology that is adopted becomes the focus of improvement: experience is gained with this technology and so it progresses – increasing its positive returns to adoption. As it becomes more attractive, the likelihood of others adopting it increases still further; creating a network of users. The cycle continues: the more it is adopted, the more it will remain the focus of improvement, the more it will show increasing returns to adoption.

Because of these social processes, the adopted technology has a better chance of becoming dominant over any likely competitors. As Arthur (1999) puts it: “an industry can become locked-in to a technological path that is difficult to get away from [and this occurs because] more and more people choose [or adopt] one technology [which may well be technically inferior to others] from a group of competing others” (1999: 107). Other technologies, simply not thought of or rejected, become frozen out and dormant (Arthur, 1999; Nelson & Winter, 1977; Dosi, 1982).

This theory perhaps explains the prevalence of the gasoline car over the steam car (Arthur, 1999); the QWERTY keyboard over the Dvorák keyboard (Pool, 1997); Betamax’s submission to VHS video cassettes; Microsoft Windows’ sustained leadership over other computer operating systems; Stephenson’s 4ft 8½ inch railway gauge over Brunel’s 7ft broad gauge. Arthur’s theory (1999) suggests that widespread adoption of these artefacts has elevated them to “a dominant position over others, thus it becomes increasingly difficult to reform or reverse development towards more efficient systems.

Though this theory helps to explain the appearance of technological determinism, we should look closer at the “constant turmoil of concepts, plans and projects” (MacKenzie, 1996a: 6) at the heart of technological development. As Arthur (1999:

107) points out, “the reasons why a particular technology came to be adopted are difficult to pinpoint”.

MacKenzie (1996a) suggests that we should perceive the direction of the flow of technical accretion as being guided by what is seen as possible, realistic, and most likely to bear success, in the relevant context by the relevant community of decision-makers: “Beliefs about a technology create the conditions to which they refer” (1996a: 7). Technological development is underpinned by an “institutional pattern of predominantly incremental change involving, centrally, a self-fulfilling prophecy” (MacKenzie, 1990: 385).

1.7.5 Robert Merton’s “The self-fulfilling prophecy”

W. I. Thomas once wrote: “If men define situations as real, they are real in their consequences” (cited in Merton, 1957: 421). The theorem is explained in Robert Merton’s well known parable concerning *The Last National Bank*. The bank was a successful, flourishing business, yet events on what was to become Black Wednesday saw to the bank’s collapse. A rumour suggested that the bank was on the brink of insolvency and, believing the rumour to be true, depositors entered the bank frantically seeking to salvage their own. The actions of depositors brought down the bank: the prophecy of the collapse led to its own fulfilment (Merton, 1957: 422 - 3). The parable teaches us a valuable lesson: “definitions of a situation become an integral part of the situation and thus affect subsequent developments. ... [And it is] instructively applicable to many, if indeed not most, social processes” (Merton, 1957: 423; 421). This is what MacKenzie (1990) found in his research on missile accuracy: “Improvement mainly came about by identification of the barriers to accuracy in existing systems (rather than discarding them) so as to remove these barriers. Extrapolating that process of incremental change into the future, the proponents of inertial guidance have prophesied what they will be able to achieve if given the resources to do so” (1990: 385 - 6). In sum: “If it comes to be believed that there is

only one way to advance a technology, then that one way at least has a chance of becoming reality” (1990: 391).

Merton’s and MacKenzie’s work reminds us that a self-fulfilling prophecy need not be “invested with internal logic, or through intrinsic superiority... Its continuance becomes embedded in actors’ frameworks of calculation and routine behaviour, and it continues because it is thus embedded” (MacKenzie, 1996a: 58).

1.7.6 Thomas Kuhn’s “scientific paradigm”

We are drawn irresistibly to Thomas Kuhn’s work on scientific paradigms (1962 & 1970). On the most common interpretation of it, his work “depicts most science as taking place inside a paradigm – a set of beliefs and expectations that guide research, defining which questions are important and designating the proper ways to go about answering them” (Pool, 1997: 13). Kuhn describes how this way of working comes about:

A scientific community consists, on this view, of the practitioners of a scientific speciality. To an extent unparalleled in most other fields, they have undergone similar educations and professional initiations; in the process they have absorbed the same technical literature and drawn many of the same lessons from it. Usually the boundaries of that standard literature mark the limits of a scientific subject matter, and each community ordinarily has a subject of its own. ... As a result, the members of a scientific community see themselves and are seen by others as the men uniquely responsible for the pursuit of a set of shared goals, including the training of their successors (Kuhn, 1970: 177).

These social mechanisms often become embedded in an organisation and become the basis for future work (MacKenzie & Wajcman, 1985: 11). As Kuhn points out, this definition of “paradigm” “stands for the entire constellation of beliefs, values, techniques, and so on shared by the members of a given [in this case technological] community” (Kuhn, 1970: 175).

The notion of “paradigm” can however be used in many senses. In particular, beneath the “entire constellation” notion of “paradigm” lies another sense of the word, one in which it “denotes one sort of element in that constellation, the concrete puzzle-solutions which, employed as models or examples, can replace explicit rules as a basis for the solution of the remaining puzzles of normal science” (Kuhn, 1970: 175).

Technologists operating with a paradigm thus take previous technical achievements and model future work on those achievement (MacKenzie & Wajcman, 1985: 11).

This process is not challenged by group members, but the paradigm, is instead, extended and exploited in a variety of ways (Crombie, 1961: 358). But, as Kuhn asks: How has the group member learnt legitimately to manipulate the paradigm logically and mathematically (Kuhn, 1970: 189)? Kuhn proposes that, once the new group member is sensitised and immersed in the aforementioned constellation of beliefs, etc., he will confront his work “in the same gestalt as other members of his specialist group. ... He has meanwhile assimilated a time-tested and group licensed way of seeing” (Kuhn, 1970: 189).

In this way, a paradigm does not *explain* why a technology is the way it is. It “is not a *rule* that can be followed mechanically, but a *resource* that can be used: it can be manipulated to serve several different needs” (MacKenzie & Wajcman, 1985: 11).

1.8 THE SOCIAL CONSTRUCTION AND MANAGEMENT OF RISK AND THE CHALLENGER DISASTER

If technological paradigms can be “subjected to logical manipulation” (Kuhn, 1970: 187) by users as a “puzzle-solving enterprise” (Kuhn, 1970: 183), associated perceptions of risk must be linked to communities. Anthropologists such as Douglas and Wildavsky (1982: 2) tell us: “there is a diversity of risk perspectives”, which are products of the community’s institutional, cultural or political worldview (Cutter, 1993; Nelkin, 1985: 20). Each social arrangement elevates some risks to a high peak and depresses others below sight (Douglas & Wildavsky, 1982: 8):



Whether two things are similar or different, always involves a human judgement. We make such judgements routinely in our everyday lives. Things appear similar or different depending on the context of use (Collins & Pinch, 1997: 38).

Risk assessments of technology rest upon the relevant community (MacKenzie, 1996b: 259), which must assess and prioritise problems, consequently non-technical and cultural influences can impact on risk assessment. Vaughan's (1996) Challenger disaster study underscores this point.

Rubber-like O-rings within the joints of the solid rocket boosters (SRBs), (designed to seal a tiny gap created by pressure on ignition) deviated from their expected performance when temperatures were colder than normal. The launch date was January 28th; it was a particularly cold day (Punch, 1996: 28). Why was Challenger permitted to take off?

NASA's work captured the American public's imagination. Triumphant space missions occurred regularly, cultivating self-confidence. The majority of the American people admired the valour of 'their' silver suited astronauts. They marvelled at the painstakingly scientific and technological work of 'their' rocket engineers. The flamboyant scene of yet another space shuttle entering orbit and being a leading force in cutting edge technology manufactured a 'can do' attitude within NASA's workforce (Vaughan, 1996: 209). The 'can do' attitude was not an uninhibited 'gung-ho' attitude, but an attitude that attempted to symbolise NASA's pure technical culture. It symbolised, "a commitment to research, testing and verification; to in-house technical capability; to hands-on activity; to the acceptance of risk and failure; to open communications; to a belief that NASA was staffed with exceptional people; to attention to detail; and to a *frontiers of flight* mentality" (Vaughan, 1996: 209): NASA engineers, on a daily basis, dealt with the construction, interpretation and definition of risk, failure and success.

The problem with the SRBs' performance when exposed to cold temperatures was noticed in 1982 and a decision had to be made about it: how risky is it in terms of the whole project? "Engineers ran tests to determine the safety margin. Determining that the maximum amount of erosion possible would still not fail the joint they concluded that the joint was an acceptable risk. An unpredicted but localised anomaly had occurred. They believed they understood what caused it. They fixed it, and altered ongoing research to incorporate new tests in order to improve joint performance" (Vaughan, 1996: 244). This process conformed to the basic universal, work ethic of the engineering craft. Develop work around developing technology on an *ad hoc* basis: this process of decision-making became the normative framework for the future and a risk culture was created (Berger & Luckmann, 1966: 71 - 2).

This culturally embedded decision-making process was transferred to a new administrative set-up brought in by President Reagan. Reagan's administration increased the interface between government and business. Contracting-out became institutionalised, making business enterprise a permanent aspect of NASA structure. NASA was under increasing pressure to do business with business. Control at the top, superior-subordinate relationships, orders, close supervision, rules and regulations, and hierarchical reporting relations began to dominate NASA's technical culture. The ensuing Challenger project was conducted with bureaucratic proceduralism and hierarchical relations and with the 'can do' attitude (Vaughan, 1996: 209). Incorporating contractors resulted in additional administrative structures and procedures to co-ordinate and control NASA-contractor relations. To conform, NASA increased its non-technical staff, expanding its administrative structure still further. Subsequently, professional accountability struggled to survive as the agency adopted the trappings of bureaucratic accountability (Vaughan, 1996: 211).

The effect was a deluge of paperwork that structured and defined *the* decision-making process for future problems: the original, institutionalised paradigm was formally developed into paperwork as guidelines for engineers to follow meticulously. They

could go by the book, but competing factors in the new bureaucratic set-up fuelled problems:

The incursion of bureau-pathology and production goals into the NASA culture did not eliminate the priority of safety concerns that typified the original technical culture, but eroded it by making practices associated with it more difficult to carry out... Costs and schedule concerns had to be balanced with safety not just because safety was one of the prescriptions of the engineering craft but because failure, and responsibility for it, was something no-one wanted (Vaughan, 1996: 227).

The result: the original *can-do* technical culture was applied in an increasingly restrictive environment, where engineers had to “go by the book” and “align actions with procedural rigour” (Vaughan, 1996: 234). The engineering workforce adhered to the historic ‘can-do’ spirit and decision-making paradigm within an environment that was distinctively different to the one in which both had originated in. In contracting-out times it was vice-versa - the process was not *ad-hoc*. Work methods struggled and came into conflict with the new, static administrative environment. NASA engineer’s work resembled more and more the work of an administrator – red-tape adherence.

Concomitantly, a sense of engineering autonomy or creativity was stunted leaving no room for engineering judgment or “hunches” in the decision-making process. Their work was bracketed by programme decisions made outside and above the lab (Vaughan, 1996: 204).

Harry Braverman’s (1974) “deskilling theory” pointed to a separation of the working hand from the thinking brain¹⁵, similarly - NASA technicians’ “control over their craft

¹⁵ Despite it being highly regarded by many, particularly those with Marxist leanings, Harry Braverman’s theory has been robustly criticised. As MacKenzie (1996a) rightfully reminds us, the deskilling theory’s arguments concerning homogenization “are precisely a *tendency* – *no more*. The imperative of valorization does bring about

was altered when planning responsibilities were taken from the individual craft worker and shifted to managers [engineers were thus] mere carriers of an organisational belief system ... of which there is a preoccupation with cost and efficiency, conformity to rules and hierarchical authority” (Vaughan, 1996: 205).

1.9 A POST-INDUSTRIAL TREND: THE EFFICACY OF THE WRITTEN RULE

1.9.1 Engineering as a bureaucratic profession

Leaders of technological organisations now increasingly aspire to control their workers and technological development through formalised knowledge. Knowledge is formulated into rules and disseminated throughout the workforce, delineating exactly how to work (Hale et al, 1998: 165). Readers of Michel Foucault’s *Discipline and Punish* (1970) will be reminded of his thoughts on the growth of organised knowledge. Schema, like timetables, taxonomies, typologies, and registers, he said facilitated the control of large numbers within a regimented space. Administrative mechanisms are typically concerned with surveillance and control subordinating bodies to rules of practice (cited in Featherstone et al, 1996: 158).

Formalised knowledge is thus increasingly displacing empirical knowledge because of its presumed cost and time advantages¹⁶. Rules and regulations are common

changes in the labour process that do away with capital’s dependence on many human competences that once were necessary, these changes do undermine the position of groups of workers who owe their relatively high wages or ability to resist capital to their possessions of these competences, and technology is crucial to this process. But these changes in the labor process also create the need for new competences, create new groups of *skilled* workers, and create types of work that are far from exemplifying the subordination of labor to capital” (1996a: 39).

¹⁶ Theoretical knowledge carries benefits in time and cost management: engineers do not perform trial and error experiments on every component: indeed Pool (1997) says “It would be impossible to develop a plane with six million parts by trial and error. There aren’t enough people in the world to perform all the trials, nor enough time before the sun dies” (Pool, 1997: 121). However he reassures us when he writes: “At the same time, no-one would ever attempt to design a plane with six million parts unless there was some *a priori* reason to think it would fly...

features within workplace settings: what has become decisive for the organisation of decisions and the direction of change is the centrality of theoretical knowledge – the primacy of theory over empiricism and the codification of knowledge into abstract systems of symbols [i.e., rules for procedures] (Bell, 1974: 19).

1.9.2 Labelling a problem (or constructing a language)

Codification of knowledge requires leaders to “define” and “label” technological anomalies and problem areas. A common language tends to develop that is comprehensible only to those who belong to the technological community. A *secondary socialisation* process is marked by the: “acquisition of role-specific *special knowledge* [which] requires the acquisition of role-specific vocabularies (Berger & Luckmann, 1966: 158). Karl Mannheim (1982), similarly states: “Within [a] community, a distinctive terminology takes shape [that] acquires a distinctive conjunctively determined meaning for the narrower community, and this meaning is understood only by those who have taken part in the pattern of experience in which the word in question suddenly springs forth as designation” (1982: 197). By borrowing concepts from Scheff’s *Being Mentally Ill*, (1966) we can take a closer look at how “terms” *per se* can spring forth.¹⁷

Scheff was intrigued with the interplay between social control [rules and regulations], social organisation [technological industries], deviance [technical anomalies and defects] and identity [labelling of technical defects].... There are abundant labels and definitions which describe the character and behaviour of the mad [technical anomalies and defects]. These labels are available to those [technicians, engineers, workers] who witness strange conduct [technical deviation].... Labels [technical terms] may not be applied immediately. They may not be accepted without qualification when they *are* applied: there is often some scope for negotiation [throughout a

modern technology arises because scientific and engineering theory guides the design effort, indicating what should be possible and how to achieve it” (Pool, 1997:121).

¹⁷ In the following I paraphrase extensively Downes and Rock’s (1982) illustration of Scheff’s work. However, the words within [these brackets] have been inserted by me. I have done this to show clearly how Scheff’s work can be manipulated for a sociological study of technology.

workforce there may be different interpretations of what constitutes a technical problem, and there will be differences in interpretations as to what a problem *is*, and how it should be addressed]. But labels do embody general and seemingly objective ideas [the label - a technical term - within an instruction is seemingly so-called after vigorous, bias-free scientific processes]. Labels make sense of [technical] problems, suggesting ways in which one can, and should go mad [how a technical artefact can and is expected to deviate, (remember Wynne's and Vaughan's work)]. In particular, they inform psychiatric [maintenance] practice, providing a basis for diagnosis and treatment [planning and timetabling of maintenance and safety procedures] (paraphrased from Downes & Rock, 1982: 151).

Nelkin (1985) sums up: "Once a problem is defined, possible solutions are considered. ... As action flows from the definition, the way a problem is framed has an important bearing on what is or is not done about it" (1985: 25). For the case in point, this means that workers "frame a problem precisely, by introducing and standardising vocabulary, [a] frame provides a vision of a world in doubt... it grounds our interests" (Rein, cited in Nelkin, 1985: 20).

Workers, therefore, can refer to documents for best practice procedures, which however, may remove freedom (Henry, 1987). Or on other occasions, interpretation of wording may be gratefully seized upon by those required to conform to the rule (Hale et al, 1998: 167). Such shortcomings are the focus point for the next section.

1.9.3 Responding to Three Mile Island: Thousands of work steps.

After Three Mile Island, the Nuclear Regulatory Commission encouraged utility managers to develop a comprehensive set of work procedures. Compliance with these procedures, the commission reasoned, could prevent accidents. At Ocean Reactor¹⁸

¹⁸ Ocean Reactor is a fictitious name used by Hirschhorn (1993).

managers developed over a thousand operating and maintenance procedures (Hirschhorn, 1993: 139).

Plentiful procedures, Merton (1957: 198) argues, exert a “constant pressure upon the official to be methodical, prudent and disciplined.” At Ocean the constant pressure did not yield and employees found themselves under increasing pressure to go by the book: an activity termed as *verbatim compliance*. This was increasingly difficult to do in most occasions and simply impossible to do in others. Compliance with the verbatim left no space for procedural deviation, yet deviation was needed as some procedures, which ran into thousands of work-steps were “incomplete, contradictory and inaccurate” (Hirschhorn, 1993: 139). This was common after design modifications and the issue of new broad policy statements. New statements, written by senior managers, had a huge impact on supervisors as it meant they had to re-write two hundred other test procedures unexpectedly” (Hirschhorn, 1993: 139). Exacerbating this problem was the inability of the verbatim compliance philosophy to account for the critical role of tacit know-how. Therefore, many of the printed regulations were incomplete. One supervisor sums it up: “No procedures, however well written, can substitute for technical knowledge” (Hirschhorn, 1993: 139).

Verbatim compliance left the employee in a precarious situation. Precise written procedures made operatives feel that he or she had to adhere unequivocally, but when the operative “knows” something is wrong with the written order, dilemmas are created. “If a procedure is wrong, incomplete, or contradicts another, what should the mechanic or operator do?” (Hirschhorn, 1993: 140). The worker felt “accountable for mistakes and would be personally fined or punished. If he violates a procedure, even if he’s right, he’s wrong: if he doesn’t violate a procedure and it’s wrong, he’s wrong” (Hirschhorn, 1993: 140). The outcome of such organisation could be a self-inflicted catastrophe, as one manager put it: “The next major accident in the nuclear industry will be caused by operators following procedures” (Hirschhorn, 1993: 140). In efforts to protect themselves, (and the power plant) engineers and middle managers

“subverted formal management processes to meet management’s expectations”. This meant that engineers and technicians “feeling unprotected, would hang back and either follow bad procedures unthinkingly or correct them carelessly” (Hirschhorn, 1993: 139).

The organisational system at Ocean Reactor emphasised the role of rules and procedures or as Hirschhorn (1993) says, there was an authority based on “rules rather than roles”. There was a *displacement of goals* from “end-centred” to “means-centred”:

This very emphasis (of rules) leads to a transference of the sentiments from aims of the organisation onto the particular details of behaviour required by the rules. Adherence to the rules, originally conceived as a means, becomes transformed into an ends-in-itself; there occurs the familiar process of displacement of goals... Discipline, readily interpreted as conformance with regulations, whatever the situation, is seen not as a measure designed for specific purposes but becomes an immediate value in the life-organisation of the bureaucrat. This emphasis, resulting from the displacement of the original goals, develops into rigidities and an inability to adjust readily (Merton, 1957: 199).

Ocean Reactor leaders did not assume leadership roles fully; they did not manage the risk of the enterprise fully; they could not delegate authority and they tried to use technically developed procedures and rules as a substitute for roles. The structure promoted:

Functional or instrumental rather than substantive rationality. Since, in this ideal-type state the rules are complete and consistent, authority is vested in the rules and people need only to follow these orders (Merton cited in Hirschhorn, 1993: 146).

1.10 TACIT KNOWLEDGE AND NON-VERBAL THINKING

1.10.1 Distributed cognition

At Ocean the written rule was unable to cover all eventualities because some management techniques required either tacit knowledge or non-verbal thinking. In

this sub-section we look at the latter and how it matters for organisational communication. Firstly, we should absorb this thought:

In no society does a member face demands for response in isolation. Always, when she has a choice to meet demands, there is a backdrop of social relations via which the necessary resources are channelled to her (Barnes, 2000: 96).

Barnes then suggests that when a society is close-knit (i.e., small work-groups), strong reciprocal pressures can be generated, thus members are called on to help and assist [workmates] (2000: 96). Thus: "It is through participating in the community that individuals... learn the logic of the system and their own role" (Hutchins cited in Sanne, 1999: 33). Moreover, mutual dependence and shared tacit understandings can be generated within the group (Berger & Luckmann, 1966: 158) which each member is expected to maintain (Goffman, 1959: 88):

Accomplices in the maintenance of a particular appearance of things ... are forced to define one another as persons 'in the know' ... [Members] tend to be bound by rights of what might be called familiarity. Among team-mates, the privilege of familiarity – which may constitute a kind of intimacy without warmth – need not be something of an organic kind, slowly developing with the passage of time spent together, but rather a formal relationship that is automatically extended and received as soon as the individual takes a place on the team (Goffman, 1959: 88).

Goffman's work can be linked to Heath and Luff's (1992) idea of *distributed cognition* which is: "A process in which various individuals develop an interrelated orientation towards a collection of tasks and activities" (cited in Sanne, 1999: 31). This idea and strands of Goffman's work are developed in Johan Sanne's (1999) study of air traffic controllers. Sanne points out how controllers developed a *common orientation* which is maintained by two components: a social component which "involves a commitment to the task and to the team" (1999: 312) in the way Goffman and Barnes mention; and a cognitive component which "includes a shared understanding of the situation and what one should do *now*, given what colleagues do" (1999: 312). The cognitive component interests us, for it relies on visual thinking and image construction.

Sanne (1999) noted how controllers often use radio communication, strips of stiff paper with information about a specific flight, radar screens, and closed-circuit TV to build up a *picture* of the traffic as a means of understanding the situation. These objects are used as an “*aide mémoire*” to plan how traffic is to be controlled; to simulate in the control room the movement of traffic; and to visualize and coordinate the traffic for themselves and others (1999: 70). The controllers do not necessarily resort to a mental picture inside their heads in the way Eugene Ferguson might mean when he refers to the *mind's eye* (1993).

Each *picture* of all the controllers *in toto* adds to an appreciation of the overall situation; an individual picture is used to *fit in* to the complete work situation. This means the picture is used to achieve a working division of labor within the team, in which everyone knows what to do *now* and *how* (Harper & Hutchins cited in Sanne, 1999: 236). Individual controllers come to *see* themselves as part of the system, knowing what to do and when. Ultimately, humans and non-humans, i.e., strips of paper *etc* (Callon, 1999: 183) are forged together to form a *culture of safety* (Sanne, 1999: 240 & 312).

1.10.2 Knowing *what* and knowing *how*: Wittgenstein's paradox

If events are *novel* though, how can people *know the best way* to deal with them? Linguistic philosopher, Ludwig Wittgenstein deliberated over such contradictions. He noted how human activity *appears* to be based on *knowing what* (Dreyfus & Dreyfus, 1986: 4). I know that $5 + 5 = 10$, and I know this because I know what the symbols $+$ and $=$ *mean*. Yet, as a sceptic might ask: How do I *know* this rule will be applicable in the future? (Kripke, 1982: 8). My certainty and confidence is driven by *something* in my mind, and this something will instruct me on how to conform to the meaning of $+$ and $=$ (Kripke, 1982: 22).

But, when I concentrate on what is in my mind, what instructions are to be found there? How can I be said to be acting on the basis of these instructions when I act in the future? ... To say that there is a general rule in my mind that tells me how to add in the future is only to throw the

problem back on to other rules that also seem to be given only in terms of finitely many cases. What can there be in my mind that I make use of when I act in the future? It seems that the entire meaning vanishes into thin air (Kripke, 1982: 22).

Languages, it seems, are “gradually established by human conventions, without any promise” (Hume, 1978: 490). Experience and perception, it seems, cannot be explained by “the application of rules to basic features. [Instead], human understanding is a skill akin to finding one’s way about in the world” (Dreyfus & Dreyfus, 1986: 4). In other words, “one must do the correct thing with them [rules] but, they themselves do not determine what this doing will be” (Canfield, 1981: 20), so basic understanding is *knowing how* rather than a *knowing what* (Dreyfus & Dreyfus, 1986: 4).

Vincenti (1990) continues this important point. Visual aids (like those utilised by air traffic controllers), and others such as sketches, drawings, images on computer screens, etc, are only effective tools if the operator *knows how* to interpret them competently. He has to possess the relevant tacit understanding, as Burns once put it: “Knowledge consists of the ability to do something. ... Knowledge is the property of people rather than documents” (cited in Collins, 1982: 45).

An important difference between members of different groups lies in the contents of their tacit understandings of the things that they may legitimately do with a symbol or a word or a piece of apparatus. ... The process of learning, or building up tacit understandings, is not like learning items of information, but is more like learning a language or a skill (Collins, 1982: 46).

1.10.3 The apprentice and the skilled practitioner

Tacit knowledge therefore, “has not been (and perhaps cannot be) formulated completely explicitly and therefore cannot be effectively stored or transferred entirely by impersonal means” (MacKenzie, 1996a: 215). Tacit knowledge, instead, is “built up by experience or is acquired by example. ... it can only be transferred by personal interaction” (Faulkner et al, 1997: 19). Collins’ seminal work (1982) regarding TEA laser construction, is particularly relevant.

In the 1960s some laboratories were intent on increasing the output of gas lasers by increasing operating pressures. No-one had successfully done this until one Canadian organisation unveiled the Transversely Excited Atmospheric (TEA) Pressure CO₂ laser (Collins, 1982: 50). Published articles soon appeared in scientific journals and patents were sold; others were able to copy the Canadian way. However, whilst some companies had some success, others failed entirely (1982: 51 - 2). One British group reported that despite creating an apparently exact copy of a successful operating TEA laser, they were at a loss to explain its failure. Part of the reason is because TEA laser development and construction did not consist of the logical accumulation of packages of knowledge (1982: 52), but required constructors to operate skills which cannot be transmitted through the medium of the written word. Indeed, during his research, Collins heard of no-one who had succeeded in building a TEA laser using written sources as the sole source of information (1982: 54). Laboratories only learned how to build a laser by calling on a specific *source* who had been involved in construction of a successful laser elsewhere. An *outsider*, who did not work in the lab where the laser was being built, had to be relied on. The source had to make personal visits, and the frequency of visits depended upon the degree of expertise already available in the lab:

For instance, a spokesman at Origin [Canadian firm] reports that it was only previous experience that enabled him to see the success of a laser built by another laboratory depended on the inductance of their transformer, at that time thought to be a quite insignificant element (Collins, 1982: 55).

The laser builders required the tacit knowledge of one who had successfully built one before. They needed at least one member of the team to *know* where to look for problems and who was likely to say without formulating explicitly but more often in the manner of: “*have you looked at component x?*” In doing so they passed on *judgement skills*. Judgement is “the feel experienced designers have for what will work, and what won’t, for which aspects ... can be trusted and which can’t [and this skill] is passed on face-to-face, person-to-person” (MacKenzie & Spinardi, 1996: 231).

“Tacit knowledge is empirically generated, it is derived through experience, experimental testing ... and generally through the use of the particular technology” (Pinkus, 1997: 33-34). This is because it is too difficult to acquire this knowledge any other way; thus “deliberate organisational learning strategies [must incorporate] on the hoof or person embodiment mechanisms of transfer” (Faulkner, 1997: 184). This means there is a need for the apprentice to learn from the journeyman (MacKenzie & Spinardi, 1996: 216).

Take the apprentice scientist for instance. She is formally trained in the laboratory – she learns her trade by working through lots of examples under supervision and through laboratory experience – she is immersed into the culture as she learns to make inductions in the same way as her peers (Collins, 1997: 129). This organisational learning strategy gives the trainee scientist the opportunity to *pick up* tacit skills which enable them to assess the merits of different experimental paths: which research directions are likely to bear fruit and which are likely to be of no consequence? To answer this, scientists must refer to tacit, judgemental skills. Polanyi (1983) eloquently explains the process:

A most striking concrete example of an experience that cannot possibly be represented by any exact theory... is an experience within science itself: the experience of seeing a problem, as a scientist sees it in his pursuit of discovery. It is a commonplace that all research must start from a problem. Research can be successful only if the problem is good; it can be original only if the problem is original. But how can one see a problem, any problem, let alone a good and original problem? For to see a problem is to see something that is hidden. It is to have an intimation of the coherence of hitherto not comprehended particulars. The problem is good if this intimation is true; it is original if no one else can see the possibilities of the comprehension that we are anticipating (Polanyi, 1983: 22).

1.11 CONCLUSION

The management of technology has been at the heart of this chapter, and this is how it will be throughout the thesis. I analyse how technical decision-making involved with rail maintenance in the industry is structurally organised; I look at how history,

culture and organisational change shape risk management and technical decision-making. I also refer to the impact of these issues on the worker in terms of (tacit) knowledge and skill development. I note the limitations of rules whilst discussing how individuals accrue tacit knowledge and how groups operate it. The theories and findings put forward by the scholars in the foregoing provide a framework from which analysis begins. However prior to presenting and analysing findings, the following chapter explains how I went about my research and gained the findings I did. I explain what methodologies I used and why.

2 METHODOLOGY

But a first hand immersion in a sphere of life and action – a social world – different from one's own yields important dividends. The fieldworker who has observed closely in this social world, has had, in a profound sense, to live there. He has been sufficiently immersed in this world to know it, and at the same time has retained enough detachment to think theoretically about what he has seen and lived through (Glaser & Strauss, 1967: 226).

2.1 RESEARCH PRELIMINARIES

2.1.1 Introduction

I now detail in chronological order how I went about my research: from deciding what to research, to reading related literature, to *finding out* about the industry, to introducing myself to the industry, to organising interviews, and to gaining access to the railway environment for fieldwork. Throughout the following discussion, I also argue why I did things the way I did. For instance I point out why I chose an ethnographic study. Firstly I explain why I researched something to do with the railway industry at all.

2.1.2 Choosing a research project

“What is the point in sociology?”

This question was fired at me during a particularly heated argument with a friend, who (A): had a misguided notion of what sociology entailed, and (B), was deliberately being churlish only to get a rise out me. I took the bait. Although I cannot remember my exact retort, I do remember it being poorly constructed (on account of the alcohol that had been consumed). I said something like: “look around you... why are things the way they are? Why do we behave the way we do? Cultures, norms... it's 'cause of things like that, but where do these things come from – that's what I want to know?”

“Why, what would it explain?” My friend continued the inquest. I then remember turning to the TV and saying that plenty of news stories would be better explained and understood after some sort of sociological investigation.

This ostensibly haphazard argument would eventually define the following five years of my working life, for the argument took place on the 18th of October, 2000: the day after the Hatfield railway crash.

When I turned to the TV, I said something like, “that rail crash... apparently they knew that rail was dodgy... why did they not stop traffic?” At this point, and having recently completed a “sociology of work and industry” course for my undergraduate degree, I went on about industrial organisations; decision-making by workers; formal and informal work procedures; workplace cultures and so on. All these things, I told my friend, must have been implicated in that crash. It was at this moment that the metaphorical light bulb appeared above my head – what a good idea for a research project, and what timing! I had just recently started my MSc and was searching for a research topic. This train crash could serve the purpose.

From such implausible beginnings I embarked on my research, and I shall now detail the directional process of my studies.

2.1.3 Related literature

During the first year of my studies I searched for literature that might suggest how I should go about my research. It was then that I was introduced to Charles Perrow, Diane Vaughan, Tom Burns and G. Stalker, and the high reliability theorists. Their work gave me a deeper understanding of “the industrial organisation”. Through their work I appreciated more the impact that an organisation’s social characteristics can have on the management of knowledge required for effective organisational

functioning. Organisational culture and decision-making, these authors told me, go hand in hand and to understand the latter, you have to understand the former.

I realised that I had to complete an organisational analysis of the railway industry if I was to understand why a train was operated over a rail that was known to be in poor condition.

2.1.4 The role of documents: foundations to learning

For much of the first year of my research I had contented myself with secondary sources of information. Documentary evidence needs to be interpreted and understood. Others (Cicourel, 1964; Bonnell, 1980; Platt, 1981) pinpoint the critical aspects of analysing documentary evidence: a document needs to be evaluated in terms of who produced the document and what their intention was; the researcher should ask whether there is any underlying bias and whether the creators of a document have a hidden motive; is the document genuine and authentic? A streamlining process has to be engineered to determine what articles can be put aside, which articles should be analysed, and which leads should be pursued. The sheer volume of documents produced in response to the Hatfield railway crash ensured this was a lengthy process.

The documents found had advantages and disadvantages. The disadvantages were obvious. If it was a newspaper, depending on its political slant, there was a skewed opinion that the crash was because of privatisation, or it was because of shortcomings in the current government's railway transport plans. If it was written by an engineer, it was incomprehensible to me for reference was made to RCF: the technical problem that I had never heard of before that was the root cause of the crash. If there were quotes from a track worker, they often referred to an environment that was foreign to me and one I could not fully comprehend. These documents, however, gave me an idea of who is involved in railway maintenance work. I learnt about the role of Railtrack and Infrastructure Maintenance Companies (IMCs), for instance. I learnt

about their professional and contractual relationships with each other and how each slotted into the organisation of rail maintenance.

2.1.5 An unsafe industry?

Documentary evidence also allowed me to dispel the oft-quoted opinion that the industry’s safety levels are at a shockingly dangerous level.

I initially set out to show how safety levels *had* fallen and that fatalities *had* increased and that the organisation of the industry *was* the underlying reason. This hypothesis was driven by the media: according to reports, travelling by train was simply not safe.

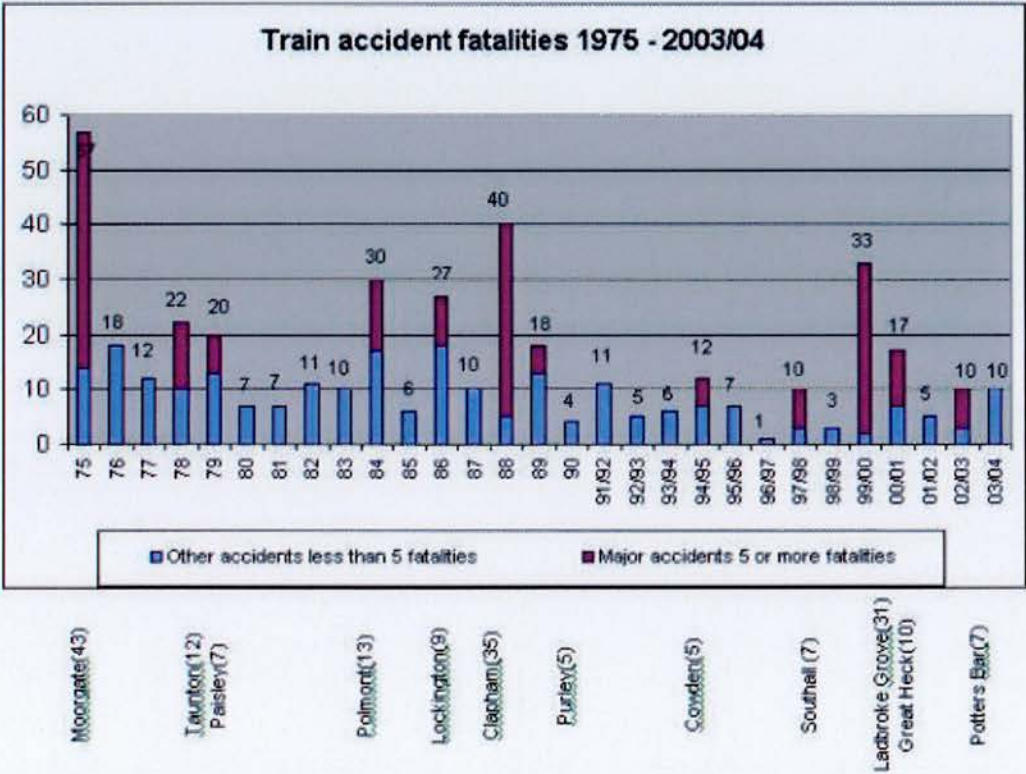


Figure 2-1 Fatality trends from 1975 – 2004 (Internet source: Health and Safety Executive website: 13th June, 2005).

Early research suggested differently, as I found that fatality rates had been dropping and continued to do so. Despite high profile rail crashes in recent years, fatality levels

are reducing in the long term – in figure 2.1 for instance it is shown how in the 11 years since privatisation (in 1993/1994) there has been 119 fatalities on the British network compared to 174 fatalities in the 11 years prior to privatisation. Furthermore, since privatisation, the number of services that operate on the British network has increased significantly (TTCI, 2000). If research were conducted that correlated traffic volume to fatality rates it could show the British railway industry is actually experiencing its safest era ever! At this stage, my research aim began to change.

2.1.6 A shift in research aims

According to accounts (International Railway Journal, January, 2001; and Railtrack, 2001a: 3) the technical cause of the Hatfield disaster was put down to a problem called rolling contact fatigue (RCF: a term for a series of cracks upon the rail's surface which, in this case, descended into the internal body of the rail causing it to fracture), which, it seemed to me, was slowly transpiring as an enigmatic problem: its exact cause was unknown, a precise solution was absent, the term seemed new to some whilst to others it was not. Given these inconsistencies, methods to manage RCF, I hypothesised, could well depend on varying thoughts of individual personnel and groups. This hypothesis was strengthened after finding out further information about the rail maintenance activities called ultrasonic inspection, rail-grinding, and visual inspection¹⁹.

Ultrasonic inspection by a train-based system, I heard, was questionable, whilst manual ultrasonic inspection (at this point in time during my research) struggled to

¹⁹ Each of these maintenance activities are described fully in chapters six through eight. For now however, visual inspection is simply that activity whereby personnel walk along the railway track looking for problems on the rail and in the railway track environment. Ultrasonic inspection is a non-destructive technique which involves an ultrasonic sound wave travelling into a rail to search for internal defects, and rail grinding is that process whereby the rail's surface is shaved to remove shallow cracking or to re-shape the rail's profile.

pick up RCF. Restarting a regular rail-grinding programme was called for by some after its near total abandonment in the 1980s; I also heard about the difficulties and limitations with a practice called “visual inspection” of rail. It seemed at the time that there were many thoughts being put forward regarding how RCF management should be conducted. Here we have technical problems that must be organisationally and collectively managed – but apparently depends on the diverging perceptions of those closest to the technology. On reflection it seemed that I had a topic that could be a novel addition to the discipline of sociology of technology.

I was now in a clear-cut position: I had to get beyond documentary-based evidence. I had to talk to railway workers; I had to hear their opinions about rail maintenance. I had to see them test a rail ultrasonically; I had to find out how this is done, and what they thought about it. I needed to walk the track with a visual inspector to find out what those difficulties were; I had to spend time with rail-grinders to see exactly what it is they do, and what their opinion is of it. I needed to see and hear about all these things if I was to complete a sociological thesis on the decision-making process involved in the management of RCF of rail and rail maintenance.

2.2 PREPARING FOR A QUALITATIVE RESEARCH PROJECT

2.2.1 Sociologists should be puzzled from the outset

I wanted to complete a qualitative study that involved interviews and an ethnography. A quantitative account that involved questionnaires and documentary analysis, I reckoned would be unsuitable for the study I now envisioned. I wanted to complete a rich contextual account of rail maintenance. Something in the style of Jason Ditton’s classic ethnography of a bakery in “Part-time work” (1977), or something similar to Gerald Mars’ features in “Cheats at Work” (1994) I thought would unravel and illustrate in clear detail the complexities of rail maintenance and the life that goes with it.

I am not a technical person. I have no qualifications in the likes of mechanical or civil engineering. I am certainly no expert in ultrasonic testing, and I have to admit to a distinct lack of knowledge about metals. Additionally, I have simply never had an interest in railways; I knew there were debates concerning privatisation and re-nationalisation, but it did not interest me – until now. Considering the topic I was about to research, some might say that this background of mine could be a major disadvantage. Indeed, I admit that the thought of interacting with professional engineers, scientists, metallurgists, ultrasonic testing (UT) operators, and trackmen filled me with apprehension. I was an “outsider” and I was going to have to talk to them in their terms if I was going to present my self as a bona fide intelligent researcher. But how was I going to talk to a UT operator, for instance, if I didn’t even know what UT entailed?

Prior to undertaking social research “the sociologist should regain a sense of puzzlement about the world. Many sociologists have lost the simple impulse of curiosity, the desire to solve riddles of experience, the concern with problems. At the beginning of every sociological investigation there has to be a fact which is puzzling to the investigator” (Dahrendorf cited in Bulmer, 1977: 16-17).

The technicalities of the maintenance activities I was about to study ensured I was puzzled from the outset, but this turned out to be quite advantageous. My research resembled the methods advocated in Glaser and Strauss (1967). Grounded theory is about the discovery of theory rather than the verification of theory handed down to us by our sociology forefathers, Marx, Weber, Durkheim²⁰ (1967: 1 - 2). This means “theory” is “discovered” during inductive sociological examination (1967: 3).

²⁰ In any case, Glaser and Strauss also suggest that sociology’s forefathers simply didn’t “provide enough theories to cover all areas of social life that sociologists have only just begun to explore” (1967: 11).

Inductive rather than a *logico-deductive* research premise (Glaser & Strauss, 1967: 31) applies pressure upon the researcher to desist from relying on preconceived ideas to guide research.

To be sure, one goes out and studies an area with a particular sociological perspective, and with a focus, a general question, or a problem in mind. But he can (and we believe should) also study an area without any preconceived theory that dictates, prior to the research, “relevancies” in concepts and hypotheses. Indeed, it is presumptuous to assume that one begins to know the relevant categories and hypotheses until the first days in the field, at least are over (Glaser & Strauss, 1967: 33 – 4).

My total lack of knowledge of everything I was about to research let me fulfil quite fully the Glaser and Strauss technique – I certainly did not know what “relevancies” would be the mainstay of my research²¹.

Research thus depends upon the “insights” of the researcher. The researcher, the authors point out, is a: “highly sensitized and systematic agent ... the root sources of all significant theorizing is the sensitive insights of the observer himself” (1967: 251). In other words the researcher should “mull over” their research: instead of defining observations as “opinions”, we should “look at them as spring boards to systematic theorizing” (1967: 252). The researcher can also “borrow insights” (say from literature) from others as long as they are not “cultivated at the expense of insights generated by the qualitative research” (1967: 251 – 2). In practice, however, this means that the sociologist has a precarious task. They must:

Balance between the two sources by avoiding the reading of much that relates to the relevant area until after they return from the field ... on the other hand some read extensively before

²¹ For instance I did not know that “tacit knowledge” was going to be a major topic in the thesis - I only realised this after completing some fieldwork.

hand, others periodically return to one or the other for stimulation. There is no ready formula, or course: one can only experiment to find which style gives best results (1967: 252).

2.2.2 Learning a language and finding out what *my* research is about

Prior to conducting any interviews and fieldwork, numerous trips were made to the science and technology library. Texts about railway construction, management, and maintenance were read. I came across technical terms that I had never heard of before, but would become an essential part of my “research vocabulary”. Instead of talking about railway tracks, it was the “permanent way”, and the “stones” beneath the track turned out to be “ballast”. And that section where a train travels from one line to another, that’s not points, it’s a “switch and crossing”, and parts of these can be made of a form of steel called “manganese” that is “ultrasonically un-testable”.

I also found out that my research was all about what happens where the train’s wheels meet the rail, or in industry-speak, the “wheel / rail interface”. What happens at this interface, it transpires, is hugely consequential for the rail, especially at curves where something called “cant deficiency²²” matters, and likewise, what occurs on the rail’s surface also matters: “wheel burns” (when the wheels of the locomotive slip as the vehicle starts to move causing rail damage), “wear”, “cracking” “shelling”, “fatigue”, and “squats” (all defined later, or see glossary), can occur and what is more, each of these either occur on the rail’s “head”, “gauge corner”, or “field side” which is sometimes known as “the cess-side” (all defined later, or see glossary), and depending on the character of the fault it may be classified to a sub-type such as “gauge corner cracking”, “head-checking”, “field-flow”, “lipping”, or “false flange damage” (all defined later, or see glossary).

²² Cant deficiency is where one rail is higher than the other at curves. This helps to ease the locomotive round a curve, however because there are many different types of traffic travelling at different speeds round the curve, the cant is not suitable for every type of vehicle – hence the deficiency.

I did not, of course, pick up immediately what all these terms meant by merely reading books. Attending two rail engineering conferences early on in my research helped significantly. At these meetings I heard people talk in these terms “naturally”, and I was able to “see” what they meant on diagrams on overheads and handouts. I saw how the terms were applied to real life situations. I now knew about their existence and I had a rough idea of what some of them meant, and at the same conferences I was able to start to talk with some railway workers, tentatively using their terms for the first time.

2.2.3 The reason for a comparative study

At these conferences I found out that other railway organisations around the globe had similar or identical problems too, yet diverging rail maintenance options were presented to the audience. I gathered that different national industries had different maintenance perspectives and utilised different methods for managing the wheel / rail interface.

Donald MacKenzie tells us that: “Sociologists of scientific knowledge have seen their task as being to explain how different groups of people come to put forward different knowledge claims, rather than to adjudicate between these claims, or to put forward an analysis premised upon the superiority of one set of claims. Faced with technological controversy, the task of the sociologist of technical knowledge is surely the same” (1996b: 248 - 9). The reason for some sort of comparative study was becoming clear: it could grant access to otherwise unobtainable and unforeseen matters that could strengthen the project as a whole. Findings from two different national rail communities could illustrate quite explicitly how rail maintenance depends upon socio-historical issues such as norms, cultures, conventions, etc. From a practical viewpoint as well of course, my findings might well suggest how each industry can learn from each other’s experiences.

2.3 GAINING ACCESS

2.3.1 Contacting British and Swiss rail maintainers

Gaining access to two different national industries was not the problem I thought it would be. My co-supervisor, Dr Schmid, is a British-based professional engineer at The University of Sheffield; he has numerous contacts in the British industry. He is also a Swiss native with contacts in the Swiss railway industry.

For my British-based research, Dr Schmid put me in touch with one engineer and after a brief phone call where I introduced myself and spoke a little about my research aim, a time was set for my first meeting. For the series of interviews that ensued, I contacted individuals who were suggested to me by the last interviewee, a process known as “snowballing” (Black, 1993: 50). Some interviewees did not mind me using a Dictaphone to record the session, on most occasions, however, they did. Rail maintenance and railway industry issues in general, as I have already pointed out, is a sensitive issue in Britain and, because of this some workers were unwilling to be recorded. When they did object they were, however, happy for me to take notes which, I ensured them, would remain anonymous. Throughout this thesis, all respondents remain anonymous; all names mentioned in ethnographies are thus false.

In any case, using a Dictaphone, I found, was often more hassle than it was worth. I found out that “ringing” mobile phones interacted with my Dictaphone to such an extent that interference drowned out my respondent. In a busy office where I spoke with many workers, mobile phones routinely rang – thus a lot of interviews were spoiled at numerous parts. Taking hand written notes was a must.

For my Swiss-based research, Dr Schmid was involved extensively. He made several phone calls to members of SBB (the main Swiss rail operator), and he gave me contact numbers and email addresses. I drafted letters detailing my research and asked if there was a possibility that I could visit the organisation to talk with workers and to

view rail maintenance techniques. They kindly offered to set-up some interviews over one week and, depending on how it went, a further two weeks could be organised for observations.

2.4 INTERVIEWING

2.4.1 Learning curves and interviewing techniques

I now discuss how I prepared for interviews and how my ability to guide conversations developed over time. What I say is applicable to my experiences in both countries. Where there were marked differences in my approach, I mention these there and then.

The more I talked with industry workers, the more I learnt and, as I progressed, my ability to converse with the respondents greatly improved²³. Nevertheless, the point remains, not only was I researching issues connected to the wheel / rail interface, I was continuing to learn about the industry all the time. This had obvious, on-going impacts on my interviewing technique.

My first set of interviews was more un-structured than semi-structured. I prepared for interviews by having a list of headings which were often labelled by those “new terms” I noted above. I let the respondents talk about these things, and they often explained them quite deeply, often by sketching. Ensuring that the respondents talked about the point at hand was not a real problem, after all, they knew much more about the wheel / rail interface than I did. They spoke at length “in their own terms” (May,

²³ Towards the end of my research I got back in touch with some of the men I had spoken to quite early on in my research. One of those I spoke to again was (Int: 01). He complimented me on how my understanding had progressed.

1997: 112) on both critical matters and matters that I simply would not have known about, given my non-technical background. Thus, trying to utilise a structured technique would have been impossible.

A key difference for interviewing in Switzerland and Britain is obviously language. Over 18 months before visiting Switzerland, I started to learn the French language. I managed to progress to a basic conversational level and, helpfully, many of the workers I eventually met up with spoke good English or broken English. Whilst learning French the conventional way – with CDs, French newspapers, BBC learning zone, and one-to-one tuition, I also had to learn technical terms. For instance, the permanent way is the *voie ferrée* (way of iron). Having some understanding of the French language helped enormously as much of my research was completed in the French speaking parts of Switzerland.

The more I interviewed workers (in Britain and Switzerland) the more my understanding of technical matters developed; through time I was able to pose “relevant” questions. In the latter stages interviews were often semi-structured, as I was able to guide conversation towards certain topics (Bell, 1993: 94) whilst using technical terms intelligently.

2.4.2 Research design and development

My research did not follow a pre-planned timetable. Instead, what I found out during one interview often suggested the next research step. The most notable instance of this was the “Personal Track Safety (PTS) certificate” example.

Time after time, interviewees ask me if I had a “PTS”. A PTS is a safety related certificate that all railway workers must have if they are to get on the permanent way. And time after time, the same respondents suggested that issues would be better explained if I saw them for myself – this was the reason many respondents resorted to

sketches to explain issues. This was my first inkling that the spoken word had its limitations in rail maintenance.

The industry does not just hand out these safety certificates to anyone who may be interested in obtaining one. There is a strict process that private companies must adhere to. This meant that I had to become a member of the industry, and this involved me becoming an unpaid member of contracted staff of a rail maintenance company. An interviewee offered me this chance: I signed a contract of work; my national insurance number was required, and the amount of hours I was willing to work was accepted as nil. I signed the contract after successfully completing the three-day course and certification process required for the PTS, which also depended on passing a medical, alcohol, and drugs test.

The actual course itself involved health and safety videos, preliminary questionnaires relating to the videos and role playing²⁴. I was issued the safety rule book which I had to revise prior to the final examination.

With my PTS I was able to go on site at a (different) railway maintenance company's discretion. Over a period of roughly three months during the summer of 2003, I accompanied visual inspectors (at night and during the day), ultrasonic operators (typically at night) and manual rail-grinders (always at night). Work on the permanent way is done during a "possession," meaning, where engineers take possession of the line (see chapter eight, page 236 for possession planning and problems). Possessions

²⁴ I had to pretend, for instance, that I was at the scene of an accident or hazardous situation, such as seeing a broken rail. Depending on what equipment I had, I would have to do slightly different things. But typically I would have to contact the signaller or electrical control office telling them my location whilst using the phonetic alphabet and other appropriate railway terminology. I would then describe the problem and what I require – block the line [to traffic], for example.

during the night are typically planned to start after the last service has passed. This meant that I often travelled to different sites for work, with workers at around about midnight. Possessions often finish in the region of 5am – give or take an hour or two.

On my first day of my second visit to Switzerland, I was given a detailed timetable of all the places I was going to visit and the people I would meet during rail maintenance. Most of the work I describe from my research experience in Switzerland (in chapter nine) was completed during daytime.

2.5 FIELDWORK

2.5.1 Secret societies, trust, being accepted, and learning how to interact

Erving Goffman once said about social research: “any group of persons – prisoners, primitives, pilots or patients – develop a life of their own that becomes meaningful, reasonable and normal once you get close to it, and a good way to learn about any of these worlds is to submit oneself in the company of the members to the daily round of petty contingencies to which they are subject” (cited in Gilbert, 1996: 156).

I got close to those petty contingencies and, as a result, I found that the whole experience of being at a possession added flesh to the bones of material I gathered from interviews. On the whole, attending possessions was a completely different matter to the interview set-up.

During my first stints of fieldwork, it tended to be just the supervisor of the UT group or grinding group who knew that I was *coming along to see things*, thus when I turned up and met the small groups of workers I was going to watch, I was often an unexpected addition to the small squad. Such a situation has profound implications from both the researcher’s and the workers’ point of view. To the group, *why I was there* watching *them* was hugely important. The opportunity for me to join a working

group was initially organised by senior management based in offices. Thus, it was conceivable to the group that I might be there to “spy” and to report back to senior managers (May, 1997: 142). This suspicion was eased over time however, and quite often at the end of a night’s work I would organise with the team members when I could next come along to a possession with them. This required the swapping of personal mobile phone numbers; something that the men I was with did not mind after getting to know me. Indeed, on some occasions, a member of the group, or the group itself would drive to my home and pick me up if there was work to be done in the area. This, I believe, is a strong indication that I was accepted by the group, and that they had a significant level of trust in me.

At the beginning, however, I was an outsider and I would have to be accepted (Bell, 1993: 10) if my research was going to work at all. In his paper “Good People and Dirty Work” Hughes (1964), wrote: “We are dealing with a phenomenon common in all societies. Almost every group which has a specialised function to perform is in some measure a secret society, with a body of rules developed and enforced by the members...”. For my work to be successful, I had to be accepted by the secret societies I was going to watch.

The teams of manual rail-grinders and UT operators – who often also act as visual inspection teams – were normally made up of three to four men and a supervisor. Depending on the possession start time, the supervisor would ask the team to meet up at location “x” – this was typically a yard where equipment is stored. The UT operators, for instance, would test (calibrate) their machinery here. Once this was done, we would all climb aboard a van and travel to the site. The time in the yard, the time in the van, and the time waiting in railway sidings for the possession to start, was absolutely invaluable to me. It gave me a chance to talk with the men I was going to watch. I could tell them all about my research; I was able to ask questions, we had numerous chances to converse about their work and mine. This was incredibly important, for it slowly allowed them to see who I was and what my agenda was. I

firmly believe that those moments prior to any work getting done, and when we had the chance to talk informally, helped me to become accepted.

Simply writing notes had to be accepted by the workers. The men's trust in me was critical, and therefore, I made it clear on all instances of research (when I met new workers) who I was and what I was doing. I ensured the men that they would be anonymous in any likely papers; this was important given the current climate and sensitivity of safety of rail maintenance in Britain. This, I believe, let them speak to me (and behave) openly, honestly, and most importantly, normally.

After meeting up with the same groups after a few nights, I felt I was accepted to a significant degree²⁵ judging by the nature of the conversations I had with the men. For example, we shared jokes, but I was also able to empathise with them about working during the night. We often spoke about our sleeping patterns during the day, and we had the same moans if the day was particularly bright and sunny and disrupted our sleep. To a certain level, my daily routine became the same as that of the railway workers I was watching. This again, helped me to become accepted by the group as I had the same gripes about the rail maintainer's lifestyle.

2.5.2 Interpreting proceedings and the role of the researcher

Those occasions when we were waiting and when we chatted, had added importance to me as a researcher. It gave me time to test my knowledge of rail maintenance. This is related to another important methodological issue – interpretation and validity (Burgess, 1984: 143; Dey, 1999: 24). How do I know that my interpretation of things

²⁵ I don't know if I could ever consider myself as being "fully" accepted. I was, to start with, an outsider, and though I got to know the men, and was able to chat quite comfortably with them in the end, I, in a sense, will *always be* an outsider. I am social researcher watching *them*, I am not a UT operator or hand grinder in "their group".

is a valid reflection of what occurred? In my case, the actual research environment gave me numerous chances to clear up any queries. There is a lot of “waiting” involved with railway work, so during these moments I was able to run my ideas and understandings by the workers I was with – they corrected me and made issues clearer. My understanding was refined continuously. Furthermore, I contacted some interviewees after our meetings to clarify points, and I wrote two papers during my research period which were read by some industry members. Feedback was positive and they indicated that I had developed a clear understanding of the issues discussed in the thesis.

As a researcher, and as an outsider to the workgroups I watched, I must acknowledge that my mere presence will have had an effect on the situation. By what I have described regarding my relationship with the group members, I would suggest that the consequence of my presence was minimal in terms of the actual work that the men did. I hope that this is borne out through my accounts of their work in later chapters.

2.6 ORGANISING AND ANALYSING DATA

2.6.1 Filing systems

For my ethnographic study I completed a comprehensive diary and transcribed dozens of interviews which required circumspect analysis. Glaser and Strauss (1967: 43) say “collection, coding and analysis of data [should be] done together as much as possible. They should blur and intertwine continually from the beginning of an investigation to the end”.

For my analysis I created an ongoing filing system. Themes were indexed and categorised – which enabled effective compilation and division of numerous sub-topics. This process was assisted by a coding system that enabled cross-referencing of interview and observational data: trends in terminology, skills, history, risk interpretation, respondents’ thoughts, and further themes were drawn out (Sanne,

1999: 54; Lofland, & Lofland, 1995: 131 - 135). This process was completed in a traditional way. My analytical and filing system consisted of numerous folders with headings, ideas and topics. Laid out on my office floor, I shuffled the topics around which let me “see” trends and suggested ideas which would be inserted into a “thesis map” illustrated on a large white marker board.

2.6.2 Taking notes and my tacit knowledge development

In writing an ethnographic-based thesis, there is pressure on the author to show that he or she “was there”, and that what is written is a true account of what he saw. He or she has to “make it real”. As Dalton (1959: 61) points out: “The social investigator must sort out his values and obligations and weigh them repeatedly throughout the research process... he is committed to give as clear a picture of what exists as his limitations allow”. Correspondingly, my aim was to capture and record accurately what I saw. However, the railway environment made it impossible for me to write up full notes there and then.

I had to conduct my observations largely at night. So I often observed detailed technical work (such as the detection and treatment of tiny, scarcely-visible flaws in the rail) at 2.00 a.m. or 3.00 a.m., in darkness and sometimes in cold weather and pouring rain! At other times, I was observing groups of workers in daylight hours, but with the constant danger of an express train suddenly appearing around a bend in the track. Because of this I tended to write down key words, terms, and drew diagrams. When the men were not working and when it was safe, I was able to “fill in the blanks” by asking supplementary questions. Once the possession was over and I was home I was able to complete a diary. Several notes from this diary are replicated in the following chapters.

These diary entries are full of detail that does not necessarily revolve around specific technical work procedures. For instance, I do not merely describe how, say, UT, is completed as a technical exercise. Instead, I show how the actual process of

ultrasonically testing a rail is part of a social system made up of individuals and groups who interact with: each other; the machines they use; and the environment. This means that I give lengthy accounts of activities which at first glance may appear to be quite unrelated to the overall issue, but which show, ultimately, what *is* required for successful UT. In much the same way as Burgess (1984: 169), “my notes were predominantly descriptive and aimed to provide a detailed portrait of the various situations in which I became involved. The field notes included physical descriptions of situations and informants, details of conversations, and accounts of events ... I focused upon the words and phrases that were used so as to provide an almost literal account of what had been said”.

Like Burgess, I was able to “build up a portrait of the relationships in particular settings and of the structure of particular groups” (1984: 169). Focusing on, and extensively detailing, the seemingly “mundane” or “unrelated” has further worth. What may be perceived as mundane I found, is typically the normal order of routine work practices which, on analysis, turn out to be quite complex and not necessarily straight forward (Lofland & Lofland, 1995: 133) By focusing on the typical work practices involved with UT and manual rail-grinding, for instance, we see how the label “routine work” is actually a misnomer. Instead, the processes that underpin seemingly “routine work” are tightly coordinated, complicated and rely on tacit understandings.

On occasion I did not merely observe; on some nights the workers let me participate in activities. In chapters seven and eight respectively, I describe my efforts at UT and magnetic particle inspection, but it is in chapter six – the visual inspection chapter – that I am able to give “my account” of the tacit knowledge that I developed as I became socialised into railway maintenance work. Searching for minute cracking, I point out, is extremely difficult – being aware of numerous variables such as light, shadows, and dampness all affect how one sees the rail. Thus it was not until a few days had passed that I was able to gain an understanding of these matters and how it is

one comes to “see” light cracking. I describe, in chapter six: 6.5 page 169, how one isolated crack *swims into view* only after the “trained” eye “knows” what to look for.

In these instances I demonstrate how I became a small part of the rail maintenance workforce. I was not just watching and describing: I was able to give my experience – indeed in chapter six: 6.5.7 page 178, I describe one event which shows some consequences of becoming a socialised “visual inspector” of the permanent way. In the words of Marshall and Rossman (1995: 16), I would suggest that from “real world observations, dilemmas and questions have emerged from the interplay of the researcher’s direct experience, tacit theories, and growing scholarly interest”.

2.6.3 A note on the text

In the following chapters I refer to quotes from interviews, these are off a smaller font and are closed with (Int: xx). Excerpts from my fieldwork diary are written in **Tahoma**, and are closed with (Fw: xx). Though the fieldwork notes detail my observations, there are on occasion direct quotes from workers, they are written in “*Tahoma italics*.”

3 BRITISH RAIL, ORGANISATIONAL CULTURE, AND PRIVATISATION

Because interchange of structure and function goes on over time, a natural history of an organisation is needed: We cannot understand current crises or competencies without seeing how they were shaped (Perrow, 1972: 175).

3.1 HALCYON DAYS?

3.1.1 Introduction

In this chapter I deal with the culture of British Rail (BR) and how it affected the privatisation process. By referencing words and memories of some of those who worked for BR and who are now retired, semi-retired or still working in the privatised industry, we garner an insight into how work was organised. We see how knowledge about the permanent way was stored and preserved, developed and utilised. We will see how a certain sense of community enabled the perpetuation of this knowledge: it will be shown how permanent way assets were managed. The idea of an *asset register* will be explained through a discussion on the privatisation process, and how the industry lost critical maintenance knowledge. Initially, I look at the organisation of BR and how it affected maintenance activities *after* privatisation.

3.1.2 The Organisational Culture of British Rail

Birmingham's National Exhibition Centre is the location for a massive railway industry exhibition that is held biennially. At one exhibition a retired railwayman told me:

Before privatisation management was not so specific, I was a maintenance engineer. I was responsible for a certain length of track. I had a sense of ownership; others like me had the same philosophy (Int: 18).

Once, as I am being driven to a site on the West Coast Main Line, the driver, who has been in the industry for the 30 years tells me:

BR had its faults, but it had a lot of good. We were lucky at this IMC [Infrastructure Maintenance Company], we call ourselves railwaymen – I am a railwayman. When you meet other railwaymen or just telling people in a pub or on holiday that you're a railwayman there's immediate rapport. There used to be 152,000 of us. ... There's a kind of selfishness – we want our place to be ship-shape, we're all railwaymen and you don't want a derailment in your area, we feel sorry for the other guy when it's happened in his. But now it is split into little money making machines... And now when you're working, it's... you know what I mean... they're not railway men, they're contractors. You don't mean any harm by it, but that's just the way it is (Int: 08).

Elsewhere I am in a van parked by the side of a railway. It is nearly 1AM and we are waiting to hear from the Person in Charge of Possession (PICOP²⁶) to give us clearance to get on site. It would be an eerie place to be if it were not for the vans by the railway side and the dozen or so men in orange fluorescent jackets who are dotted around the area. They are either unloading machinery, talking to each other, using mobile phones, or perusing papers. I ask a railway worker for his thoughts on BR and the organisation today:

Privatisation ruined the railway. At [location x] you walk past people in jackets with a different company name on the back and no one speaks to you. But we did when it was one company. You don't know them now; and you don't know how they work if they're not going out of their way to speak to you (Fw: 02).

Back in Birmingham's Exhibition Centre another retired railwayman gives me his account:

²⁶ Pronounced – “PIE-COP”

For track inspection I would walk from Pontefract to Wakefield on the Monday; then back again on the Wednesday. The walk was done in the morning; then back in the afternoon to repair what was found. ...The gang would do the job there and then; they wouldn't know what the job was until they got there. But you were asked, or you would ask - *do you think you could do that* - people spoke to each other. Then at the weekend it was lengths of the Pontefract to Nottingham line. You had to travel, always travelling to different areas, used to see a lot. You enjoyed it. You knew what was going on (Int: 14).

The differences between communicating knowledge about the permanent way during BR and privatised times were again referred to by another retired permanent way engineer:

During the BR days it was very good, if you didn't know the answer to a maintenance problem, you would ask a colleague. If there was a problem you didn't know or understand there was always someone who did know. It was a closed community in that sense, now there's a loss of networking (Int: 18).

A lack of networking, a lack of communication, a loss of community, and a lack of knowing what is "going on" in the private industry was illustrated to me quite perceptibly during one episode of fieldwork.

The scene: I am being driven to a site; there are two other railway workers with me who together, have over 60 years of railway experience. We are talking in general about BR, Railtrack, communication, and RCF:

A: There's a need to address what causes it [RCF], sometimes you need a quick fix, but you need to look at the long term. ...BR had a good research base at Derby, and we found out what was happening with a BR newspaper, but it [the research base] was sold off... Do you know what research Railtrack are doing?" [Question to me]

I answer by telling them about the involvement of WRISA (Wheel / Rail Interface Systems Authority). I have to tell them both what the acronym stands for and what the group intends to do²⁷. Neither of them has heard of WRISA. B, then points out how things can be found out haphazardly:

B: You find things out by chance now; sometimes someone in the office will have a rail magazine, [he mimics the scene] look what they saying about RCF! – [he then shrugs his shoulders].

A: It's not that bad, finally Railtrack are getting better, but there is a problem. You're not sure what is going on anymore. In the past all the records were kept at [location]. But now IMCs have their own records."

Then, as if symbolising the lack of communication in the industry, when we arrive at the site we see this: the large metal gate for access to the railway is ajar. Typically, these gates are shut and secured with a padlock. Beyond the gate there is a van with a different emblem on it from ours. It is a different company and three of its workers are by the railway side.

A: Oh, there's someone here... what are they doing... I wonder if they've got a possession?

A approaches the other workers to enquire about their business. Whilst he is doing this I ask B who he thinks they are.

B: It could be [name of contractor]... but I doubt they'll have a possession...

²⁷ WRISA will mainly collate information on RCF from different areas of academic and private industry research whilst being funded by industry members, it also intends to coordinated and enhance communication between all bodies with a keen interest on good wheel / rail interface).

A comes back to the van and says, "No, they haven't got a possession, they're planning work though, they're nearly finished" (Fw: 20).

This small incidental scene illustrates ideas of loss of networking, loss of community and shared knowledge, and so on. As a further instance, compare it to the following notes:

A railway track dissects a desolate expanse of countryside; the route joins two main towns. I am walking along this line in the 4-foot (the section of track that is between the two rails of the same line). This route and others make up a large region, the maintenance of which was once under the control of the railwayman I am now talking to.

I used to be in charge of this area, I had 447 men. There were the ultrasonics, the welders, the plate layers... I knew them all by their first name.... It's different now in the industry, you don't know who you could be working with. These guys are alright [he is referring to the three men with us; the Controller of Site Safety²⁸ (COSS), and the two look outs], they're agency, but last week I was working with a lad who was on his mobile phone every minute to his girlfriend, that's no use. I won't work with him again (Fw: 08).

Then with reference to the Hatfield rail crash and the role of "pride" in the past, another railway man with nearly three decades experience and still working today said:

Hatfield would never have happened here, that was poor. They knew about that rail and it should never have been left... that wouldn't happen here. When you're on track

²⁸ As the title suggests, the COSS ensures that safety procedures are followed. This involves discussion with the look-outs (for trains) as to where they should be positioned on the track and how they will communicate with us, and discussion with me to ensure I know where my point of safety is in the event a train comes. The COSS also takes my Personal Track Safety (PTS) certificate number at the start of the shift.

you note everything, a hole in a fence, you try and fix it there and then, even if it's just temporary, but then you go back and fix it properly, you make sure it will be sorted.... It's about pride, I don't know if it still exists in the same way since the companies came in (*Fw: 16*).

The maintainers responsible for the site at Welham Curve, Hatfield did indeed know about its poor condition. A leaked report of the official investigation into the crash (*Financial Times 08/05/01*) details this by listing the chain of events before the crash.

- 1998: Cracking in the rail on Welham Curve on the East Coast mainline first noticed by the area maintenance engineer: Rail recommended for grinding programme 1999/2000, but cancelled; re-scheduled for following year.
- Mid-1999: Area engineer decided the rail needed replacing quickly: gave Welham Curve top priority out of 10 sites.
- Early January 2000: Railtrack renewals project manager on East Coast line receives the proposals, by which time Welham Curve was on a list that was "impossible to deliver" within the existing work schedule. List sent back for prioritising: came back with six items marked "P1" (to be done within a month). Renewals manager had not seen the code P1 before and never knew what it meant.
- January 26th 2000: Jarvis, the renewals contractor sent to survey the site, but surveyed wrong site, completed second survey three weeks later.
- March 2nd 2000: Jarvis warn that one month is too tight to get so much rail renewed and to get enough welders.
- Spring 2000: Five of the six sites prioritised re-railed out-with one month time limit, Welham Curve site not re-railed. Welham Curve to be re-railed with nearby Hatfield Curve over nine weekends between March and May.
- April 28th 2000: Work gets started. But, two rail delivery trains were late and could only drop off part of their load, another could not work below the over head electricity lines. Due to delays there is only time to complete Hatfield Curve. Welham Curve not started.
- Summer period 2000: The busier summer timetable allowed fewer slots for maintenance and renewal, Jarvis understaffed with welders.

- September 2000: Railtrack arrange for grinding to start at site, but experts fear grinding might be detrimental and could make cracking worse at this late stage.
- November 2000: Welham Curve renewal scheduled to start at the end of November: six weeks after the crash (Financial Times: 08 / 05 / 01).

This timeframe suggests that a loss of networking, lack of pride, and inadequate knowledge about “what was going on” all impacted upon the crash. Problems were exacerbated because key workers had insufficient knowledge of the area and insufficient access. This underscores some differences that were intimated to me by those I spoke to. Differences in pride between “then” and “now” are apparent: pride of BR workers is strongly noticeable, when listening to them it is instantly audible, almost palpable. A sense of workers *belonging* to a region that housed its own community promoted a sense of “ownership” of an area of track; and this was helped by maintainers having uncomplicated access to “their” track:

In the past when the engineers needed their line they got it, it's not as easy as that now (Fw: 07).

Workers developed a sense of affinity with their region and knew its weak points. Knowledge was accumulated by the railway men; informal asset registers developed in the minds of regional workers:

I mean one of the fundamental problems is, prior to privatisation, there were a lot of track engineers out there, they all had their length of track that they inspected and knew very well. And they knew the problem areas. And the problem with privatisation was, there was a big loss of expertise, and with privatisation you had all these contractors coming in, and, they never had the experience. So there is a big lack of experience (Int: 27a).

Developing experience and getting to know an area required incessant learning:

I was in the industry for 40 years, and training started on day one and finished on my last day. There was no specific training, no formal training for track inspection, it was on the job. The track patroller would walk the track one, two, maybe three times a week, if you saw something you would report it to your engineer. Knowledge was passed on like that (Int: 18).

In a similar vein, others said:

Basically there was no training, it was passed on; it was all stuff you picked up and you progressed that way. It was knowledge you would pick up every day; rail alignment; twist faults; fencing, and other off track things and so on. It was all hands on. ...But progress, that's the best way to go because you need experience, you need to build on experience. You need to build on experience because you can't give a fortnight course worth of training then say go out there and know everything (Int: 13).

Training, other than p-way designers was down on the track, all hands on, nothing was done in a classroom (Fw: 09).

We can summarise what these men are talking about by referring to Railtrack's Chief Engineer:

In the past you worked in a gang of experienced people and learned what to do through a combination of instruction and emulation. And it worked (Modern Railway, September: 2002).

This method of work and learning meant that:

There was no cross fertilisation, no leadership and people on the track had their own thoughts of how to address issues on their track (Int: 03).

This was often due to geography:

Take a simple thing like flooding. We know we are going to spend a lot on flood prevention. But take a place like Cambridgeshire, there is no place to put the water. Whereas our problem is water coming down the embankments, and there is a lot you can do about that. So there are going to be different solutions in different parts of the country. A risk assessment of how you control it and put it into the current budget changes in different parts of the country (Int: 03).

Yet the point remains:

Everyone knew each other. In the areas everyone had the same knowledge, there was no need to share... this could mean there were areas of good maintenance and bad maintenance (*Fw: 19*).

BR maintenance was characterised by “regional baronies” (Wolmar, 2001: 55) where gangs of maintenance workers in different regions developed and trained their own members, and harnessed their own methods under the stewardship of a regional chief. This in turn generated a sense of pride and ownership as “work planning ... was based on a work bank with significant local discretion” (Edmonds, 2000:75). But have these memories of BR been manipulated by the passage of time and idealised? The following piece of text forces us to refocus if we think that BR was an untroubled organisation.

3.2 BRITISH RAIL: HALCYON DAYS?

3.2.1 The 12th of December, 1988

In recent years the privatised railway industry has suffered a series of catastrophic setbacks leading to calls for re-nationalisation from members of the press, the public, and politicians: their argument being that privatisation is failing and safety levels have dropped. In adopting this view, whilst accepting the words of the BR men, we might idealise BR, but we should not. The organisational structure illustrated in the last section is re-examined in the context of another BR department.

During the 1970s BR had to acknowledge the deficiencies of its *regional baronies*. To fulfil obligations under the 1974 Railways Act, BR “recognised that the existing

organisation needed to be reshaped... and the desire [for organisational] change was encouraged by the failure [of an earlier project²⁹] to transform regional management, and the consequent pressure to impose a firmer grip from the centre” (Gourvish, 2002: 24). Despite the changes that were made in 1974, BR had to concede that in places, loose, decentralised regional command, in some areas, still existed some 14 years later; and this undermined the organisation’s commitment to safety.

On Sunday 27th November 1988 one Mr Hemingway, a senior technician, was working in the relay room at Clapham Junction. The relay room controlled the signalling for the tracks leading to the Junction.

Mr Hemingway was considered by his superiors to be a very good worker. He would make his own assessment of the task in hand. He would consider it carefully. He would make the plan in his head, and then put it into effect. There were no complaints about the standard of his work. In the eyes of his colleagues and superiors he was a thoroughly competent and efficient senior technician (Hidden, 1989: 65).

Two weeks later on the 12th of December, three trains collided at the same junction. 35 were killed and hundreds were injured. The crash was caused by signal WF138 giving an incorrect aspect to the driver of the first train; a problem that was caused by the working methods of Mr Hemingway³⁰. The subsequent report (Hidden, 1989) into

²⁹ The project was called Field Organisation: “a proposal to remove one of the middle-management tiers and replacing the existing regions with eight territories. By 1974 it was clear that this attempt to restructure middle management was met with fierce resistance... and was abandoned in January 1975” (Gourvish, 2002: 11).

³⁰ “At 8:10 a.m. on the morning of Monday, 12th December 1988, a crowded commuter train ran head-on into the rear of another which was stationary in a cutting just south of Clapham Junction station. After the impact the first train veered to its right and struck a third oncoming train. As a result of the accident 35 people died and nearly 500 were injured, 69 of them seriously... They were all travelling in the first two coaches of the first train.

“It has already been established that the electrical “culprit” for the false feed of current to signal WF138 was an old wire in the relay room at Clapham Junction. One end unintentionally re-established contact with a terminal on relay TRRDM and the other was actually connected to a fuse. The current permitted to flow out to the signal. This situation was the result of electrical work done in the relay room on the two Sundays in the fortnight before the accident” (Hidden, 1989: 1 & 57).

the accident illustrated several features of organisational practices which, in the end, remind us of the rhetoric of the permanent way men who spoke to me.

The “reality” of the competencies of Mr Hemingway, when compared to how his superiors and colleagues perceived him, “was very different... many of the errors [he] made in the relay room [were] errors he had made all his working life”. They were not isolated momentary lapses; they had become his standard working practice” (1989: 65). The report did not point the finger of blame at Mr Hemingway alone; the entire organisation of BR was blamed.

That he could have continued year after year to follow these practices, without discovery, without correction and without training, illustrates a deplorable level of monitoring and supervision within British Rail which amounted to a total lack of such vital management actions ... Those charged with responsibility for monitoring and supervision fell down completely on their tasks, so did management and so did those responsible for the issuing of instructions, both oral and written, and for the provision of training, both “on-the-job” and in the classroom. ... Mr Hemingway... had a bare minimum of training on courses and no training for any technical qualification whatever. It is in light of that experience and that lack of training and of qualification that one can begin to understand his working practices (Hidden, 1989: 65 - 67).

In conclusion, a QC, stated:

I make it quite plain to you that in relation to all these matters we recognise that these are not satisfactory and indeed bad practices, but that the blame for that does not lie with you, it lies with British Rail (Hidden, 1989: 68).

Hidden concurred:

These errors of practice were not Mr Hemingway’s alone, but were part of a widespread way of working, almost a school of thought at technician, senior technician and even supervisor level

within the Signalling and Telecommunications department of Southern Region British Rail (Hidden, 1989: 65)³¹.

Groups of workers in BR tended to develop idiosyncratic ways of working. It was a practice that underpinned BR's functioning: when it failed it was catastrophic, as shown by the Clapham disaster, yet it was a valuable mechanism in terms of managing the permanent way: permanent way engineers developed in-depth asset knowledge. In the end, however, this organisational structure was to be completely overhauled.

3.3 PRIVATISING BRITISH RAIL

3.3.1 91/440/EC, the Tory party, and Privatisation

The impetus for the restructuring and eventual privatisation of BR was connected to the railway transport ideology of the Conservative government of the 1980s and early 1990s, and their interpretation of the European Commission directive 91/440.

Gourvish (2002: 259 – 262), Wolmar (2001: 58 - 85), and Hutter (2001: 263) confirm that the Tory government started discussions on rail privatisation during the 1980s. After their re-election of 1992, the Tory government led by John Major, embarked on a privatisation process that saw the enactment of the 1993 Railway Act, which paved the way for the sale of the component parts of the old BR. The Tory plan was to some

31 In depicting the findings of the Hidden report I have endeavoured to show how work was organised and supervised only. Though the report is concerned with the organisational structure of the S&T department, I think, by reference to the railwaymen above and to Gourvish's work, this structure appears to have been replicated throughout British Rail, including its maintenance organisation. In no way am I suggesting that the poor quality of the actual work of the S&T department is emblematic of British Rail as a whole. What I am suggesting is that the way work was structured and organised in this department appears to have been symbolic of British Rail's organisation (re: lack of training for instance which is mentioned in the Hidden report and referred to by railway workers earlier). Indeed as we will see later, a restructuring process was initiated with the aim of flushing out the inefficiencies connected to this organisational structure.

extent prompted by the EC directive which had come into being in July 1991. This directive included the following proclamation:

In order to render railway transport efficient and competitive as compared with other modes of transport, Member States must guarantee that railway undertakings are afforded a status of independent operators behaving in a commercial manner and adapting to market needs (Brussels, 1991. 440/EC).

The Tory ideas concerning the re-organisation of railway business and the rules imposed by Brussels connected, so when it came to utilising the EC's proposals the Party fully embraced Section 3, Article 6 of the directive: "Separation between infrastructure management and transport operations". In the eyes of the European Commission, this separation was only a must in accounting terms in that the costs of maintaining the infrastructure had to be kept apart from the costs of operating transport. The wording goes:

Accounts for business relating to the provision of transport services and those for business relating to the management of railway infrastructure are kept separate. ... This separation shall require the organisation of distinct divisions within a single undertaking or that the infrastructure shall be managed by a separate entity (Brussels, 1991. 440/EC).

Major's administration fully embraced the second option, and Railtrack was one of the first organisations created.

3.3.2 Railtrack

Railtrack³² was ultimately responsible for controlling the entire railway network; it had several activities, such as selling train paths to train operators, controlling train movements, and maintaining and leasing stations and depots. Most importantly,

³² When I refer to Railtrack – I am referring to Railtrack Plc – the operating arm of Railtrack Group.

Railtrack was also charged with “maintaining and renewing the railway infrastructure” (Glover, 1999: 6).

Though Railtrack was created to fulfil these obligations, the company itself did not do the practical hands-on work of driving trains and maintaining fixtures and fittings, instead Railtrack was the controller of who *did* these tasks. In matters of the permanent way, Railtrack decided which company had access to the track for maintenance and renewal of assets. In practice this meant that Railtrack was charged with controlling those who maintained approximately 20,000 miles of track. The idea that Railtrack should be a controlling organisation and not an “engineering organisation” was deliberate: the intention was to create an “engineering-free corporation” (Gourvish, 2002: 249).

[Railtrack] was to own the track and signalling, but not engineering activities. It was to function as an access, capacity management, and sales organisation; and it would buy in all its engineering requirements, not only physical renewals and new construction, but also with detailed inspection and monitoring functions.... Although Railtrack was to own the infrastructure, a critical feature of the new [privatised] structure was the contracting in of maintenance and renewal work in civil, signal, and telecommunications engineering, electrical equipment and fixed plant (Gourvish, 2002: 402 - 3).

The organisational restructuring processes that led to Railtrack outsourcing work are complicated, yet reference to these processes is essential if we are to understand why work was organised and described as it is in later chapters.

3.3.3 Privatising Railtrack

Railtrack was initially envisaged as a publicly-owned organisation that would supervise the role of private contracted companies (Wolmar, 2001: 86-7; Gourvish, 2002: 401). This meant Railtrack was government owned when the maintenance and renewal division of BR was being re-organised with a view to being split-up for sale to different companies. The re-organisation was coordinated under the rubric

Organising for Quality (Gourvish, 2002: 394) that was designed to flush out the BR inefficiencies which caused the Clapham Junction disaster and typified the working structure of the *regional baronies*. The result was the creation of BRIS - British Rail Infrastructure Services. BRIS's headquarters oversaw the establishment of 14 regional infrastructural units (Gourvish, 2002: 403) which would be sold to the likes of Balfour Beatty and Jarvis:

Infrastructure maintenance and renewals companies were formed out of parts of the former British Railways Board (BRB) organisation to carry out physical works on behalf of Railtrack. They were sold into the private sector, largely to construction companies (Schmid, 2001: Conference paper).

The sale of maintenance and renewal work occurred when Railtrack was not yet a private company, so during this time, it is alleged by Wolmar (2001), Railtrack had no "say" in the sale of these units. "When Railtrack was created the track maintenance and renewal companies were not part of its structure. Instead they were also in the process of being separated out from British Rail and put up for sale" (Wolmar, 2001: 89). The exchange and allocation of infrastructural responsibilities took place between BR and the maintenance companies alone: "The maintenance contracts were let in 1995" (Wolmar, 2001: 91), whereas Railtrack, it was eventually decided, was sold "to the private sector in April 1996" (Gourvish, 2002: 403). The effect for Railtrack was significant. One Railtrack manager explains how it was impossible for the company to get information out of BR about the nature of the contracts:

British Rail were saying that the contracts were commercially confidential. They did not want us to know what was in them. ... The contracts were 'closed book' which meant that Railtrack had no idea what the real costs were, nor how much profit the contractors were making (Wolmar, 2001: 89 & 91).

Effectively, this meant that "British Rail, under instructions from the government, was setting out the terms of contracts between two third parties, Railtrack and the BRIS units" (Wolmar, 2001: 90). It meant Railtrack was in charge of, and owned assets, which were being used and maintained by companies whose contracts were not

originally determined by Railtrack. This arrangement resulted in an almost total lack of asset knowledge within Railtrack.

3.4 THE DIASPORA OF SKILLS AND KNOWLEDGE

3.4.1 Shedding workers and historical under-investment

The creation of BRIS intended to flush out BR's inefficiencies. Down-sizing staffing levels was seen as essential: "necessary restructuring would require the unbundling of a very large number of individual posts" (Gourvish, 2002: 403). Figures released by the National Union for Rail, Maritime, and Transport (RMT) outline the outcome for track workers alone: in 1994, the year after Railtrack took over from BR, 21,500 workers were employed on track maintenance. By 1998 that number had fallen by 26% to 15,500³³. Jack (2001: 59) similarly points out that "between 1992 and 1997, the number of people employed on Britain's railways fell from 159,000 to 92,000. These figures are backed up with some details in a 2002 RMT report³⁴:

There are [since privatisation] far fewer permanently employed rail maintenance employees, and far more casual and agency staff who are used by contractors and sub-contractors on the network: The number of permanent staff employed on rail maintenance has collapsed since 1994, when BR began to make preparations for privatisation by making massive voluntary redundancies. Under the privatised companies, the permanent workforce has continued to fall:

Directly employed Rail Infrastructure Employees Since Privatisation

1994: 30,280

1995: 25,204

³³ The Times (20/10/00).

³⁴ "RMT submission to the Potters Bar Inquiry outlining the case for bringing all infrastructure work directly under the control of Network Rail". (Internet source: RMT website: 14th April, 2005)

1996: 22,229

2002: 18,500³⁵

Intriguingly enough the same report then points out that:

Latest figures from Sentinel in May 2002 show that the number of PTS cardholders has now risen to approximately 120,000³⁶. [However many of the card holders are temporary staff which accord with the]; peaks and troughs nature of maintenance work, and the implied dangers this creates - particularly with regard to sub-contractors:

Much of the work is undertaken at night and particularly at weekends. Such activity leads to the creation of peaks in demand for support services such as specialist plant and labour. For this reason the IMCs and track renewal companies are under-resourced from within their own organisations and they turn to their suppliers for labour to reinforce their own pool of track workers.

The report also found that many (namely, permanently employed railway infrastructure maintenance company staff – i.e. non-agency staff) in the industry had a deep mistrust of sub-contractors:

The lack of desire for ownership of health and safety issues by the [labour] agencies, not always helped by main contractors, is a major factor. Current labour suppliers are "unreliable", and have no "strong allegiance" to or expertise in the railway industry. ... The risk of vagrant workers travelling from site to site with inadequate local knowledge or rest between shifts are not sufficiently controlled.

³⁵ I gained this information from the RMT internet source: 14th April 2005, which in turn, detailed their sources as: 1994 and 1995 data from BRB (British Railways Board) accounts 1994/95; 1996 data from HOC Written Answer Dunwoody / Hill, 16th January 2001 (Column 187W), 2002 data from Rail Forum fact-sheets / RMT Membership data.

³⁶ This is same PTS card that I obtained for my research, as I detailed in chapter two.

The impact this work system has had on skills levels is noted in a Railway industry Training Council (RITC) report (2001) entitled: "Analysis of Priority Skills in the Railway industry". It states: "The issue of recruiting people to undertake skilled and operative work on the rail infrastructure is a concern ... The need for qualified engineers, technical staff, skilled employees and operatives represents a challenge for the industry" (RITC, 2001: 5 - 6).

Streamlining the workforce was designed to remove deadwood and to make the units of BR attractive for selling, but inadvertently many key workers left the industry:

While restructuring was rightly driven by a desire to remedy weaknesses, in so doing, it failed to appreciate that real strengths were also being thrown away unnoticed. These included strong industry leadership, a highly effective organisational structure and the sheer professionalism of the delivery machine (Modern Railways, March: 2001).

The legacy can be traced till recent times. In 2001, Rod Muttram of Railway Safety, said: "If our industry is going to build the bigger better railway the politicians are willing to fund, we have to recognise that we don't have the human resources to do it. We have to remember when talking about 'resources' we are really dealing with a multitude of skills" (Modern Railways, July, 2001). Thus the shortage of experienced railway engineers has been described as "worrying" (Modern Railways, September, 2002).

Compounding the situation was the level of financial input. The Railway Industry Training Council (RITC) point out: "low levels of investment during the last decades of BR left the newly privatised industry with a series of equipment and infrastructure headaches which will take many years to resolve" (RITC, 2001: 14). Similarly transport specialists – Transport Technology Centre Inc. (TTCI) - in a report for the Office of the Rail Regulator noted how this affected rail renewal trends:

There has been a falling trend in rail purchase since the 1960s... Levels of rail purchase were historically low through the mid-90s. Since the railway network has not decreased in size

significantly over this period the implication is that average rail age has been increasing. Since the number of cycles of applied fatigue stress increase with age, increasing rail age implies increasing fatigue and hence increasing numbers of defects and breaks³⁷ (TTCI, 2000: A-21).

The decrease in permanently employed track workers and the decrease in financial investment impacted on the permanent way's fitness-for-purpose. This was outlined in yet another report³⁸ which, after interviewing many industry workers, stated:

It was broadly felt that a legacy of years of under-investment in maintenance and renewal, coupled with poor asset management, resulted in the deterioration of network assets and an inability to expand and to cater for growth. Interviewees pointed out that the average age of track had increased dramatically since 1984 as a result of the reduction in renewals. Insufficient investment was exacerbated by the loss of asset knowledge at privatisation. They felt that Railtrack chose not to build an asset condition register (DTLR, 2002: section five).

3.4.2 Shedding workers: Dispensing with an asset knowledge base

On May 24, 2001 Railtrack's Technical Directorate was set up to rectify Railtrack's lack of knowledge of its own assets:

Assets are now being measured, monitored, and having their condition verified on a consistent basis across the network. ...This recognises the role that Railtrack hasn't had in the past. [This is because] Railtrack was not set up with control over its assets. Through BRIS, BR had an asset stewardship role, but this was not passed to Railtrack (Modern Railways, March, 2002).

A key reason as to why an asset register was not passed to Railtrack was due to the way BR historically managed this very knowledge during its incumbency. BR's regional permanent way maintenance communities developed and shared local

³⁷ The report's authors account for advances being made in rail production techniques such as the de-oxidisation process which is discussed in the next section.

³⁸ This time commissioned by the Department of Transport, Local and Regional Governments, 2002: "The GB Railway industry: In Its Own Words: Problems and Solutions".

knowledge of local problem spots. The methodology of developing, storing and utilising this information was not centrally controlled and stored: asset information was in the heads of the railway men. So, when the men walked away from the industry during the downsizing process, a valuable asset register left also.

The Rail Regulator, Tom Winsor, likewise suggested that problems post-privatisation were exacerbated by a lack of knowledge about the network's assets which stemmed from BR's organisation. "British Rail had a great deal of information about its assets but it was not organised in a systematic and accessible way"³⁹:

Things have got steadily worse, and now we find that the once great power house of the railway industry is in danger of stalling. How could this have come about?

I believe the answer is found in the mistakes of the rushed privatisation with too many corners cut, weak regulation and a company which squandered its skills base whilst neglecting the condition of its physical assets. ... Engineers were discarded and before long an essential skills base had been significantly diminished. ... Railtrack has no reliable and accessible register of its assets, with too much essential knowledge missing, misunderstood or locked up in the heads of people who had left the industry. For a company whose very existence is wholly dependent on the condition, capacity and capability of its assets this was a recipe for serious trouble. And that's exactly what has happened (Winsor, 2001: Conference paper).

My own research illustrates the consequences of losing knowledge about assets. At a rail manufacturing plant, a senior metallurgist told me:

The main causes of rail failure are: boltholes, star-cracks at boltholes; thermite welds [see glossary – Continuous Welded Rail]; and in 1950s, 1960s, and 1970s rail it was taches ovaes. Prior to Hatfield we carried out a major study because rail breaks were increasing and Railtrack were telling us that it was because of taches ovaes. But, because of our production process the internal quality of the rail is now hugely different. ...The whole integrity of it is better because

³⁹ (The Observer: 27/07/03). The regulator expanded on this theme elsewhere, for instance an extract of a speech delivered to the Institute of Electrical Engineers is now given (June, 2001).

of the de-oxidisation process, so we shouldn't be getting taches ovales. So we asked them to send some samples back with taches ovales. We looked at them and told them they were RCF defects. The problem was coming from the wheel / rail contact area and going down into the rail. Taches ovales are defects that are manufactured into the rail and grow outwards from within, and now, you will not find taches ovales manufactured into rails because of the de-oxidisation process⁴⁰. Railtrack were wrongly classifying defects. They lost a lot of expertise (Int: 22).

The recipe for disaster that Winsor referred to reached a climax. Spiralling maintenance and renewal costs; delays in project completion⁴¹; increased reliance on public revenue, and; the confidence of the public and its reaction in the aftermath of a series of disasters signalled the end. Railtrack Plc, during the period of this research project was shunted out of business.

⁴⁰ On the same matter, a researcher who studies the causes and manifestation of RCF, Dr Stuart Grassie, points out: "Tache ovales are associated with bad welds, though they do occur elsewhere. They are commonly considered to be defects which develop 10 – 15mm below the railhead from longitudinal cavities caused by the presence of hydrogen" (International Railway Journal, February, 1997)

⁴¹ The up-grading the West-Coast Main Line, for example.

4 CURRENT THINKING ABOUT AN OLD PROBLEM

At that moment the train was passing... And past it went, past it went, mechanical, triumphant, hurtling towards the future with mathematical rigour, determinedly oblivious to the rest of human life (Zola, 1996: 44)

4.1 A 200 YEAR OLD PROBLEM

4.1.1 Introduction

In chapter three the reorganisation of the industry was discussed in terms of the effect it had on skills levels. The impact had obvious far-reaching consequences for the private companies that came into the newly privatised industry – their personnel had to address the knowledge gap created by those BR workers who had left the industry. In chapter five we look at the make-up of one private maintenance company – we look at how it socially manages rail problems: we look at the methodologies that are used. However, in this chapter we take a moment to look at the technical side of things. We find out a little more about the fatigue of rail and what research activities are currently on-going. In doing so we find out what opinions and thoughts accentuate current thinking regarding wheel / rail interface management issues and what ideas guide the organisation of maintenance methods discussed in chapter five.

4.1.2 An old problem

During my research I interviewed a scientist concerned with the development of knowledge of the wheel / rail interface. To explain its complexity he said:

The railway's interface and the contact conditions are very important... simulations using a very simplified twin disc test, two discs rotating against each other and the contact conditions there are assumed to be similar to rail, for if you take for example a wheel and localise contact, this is also curved so it's like having two discs there. However, the complexity in real life is much more than what it is in the laboratory, it is not a one to one correlation; cracks will develop after the passage of so many wheels. It will not necessarily match with what happens here (Int: 23).

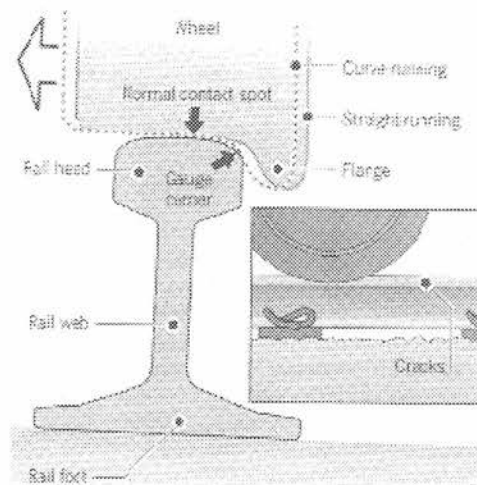


Figure 4-1 The flange and rail head relationship (source: Jack, 2001: 36).

These words were spoken by an industry scientist in 2003 and appear to concur with what others have said about the wheel / rail interface:

As carriages are kept on the rail by flanges on the wheels [see fig. 4-1], it is obvious that where curves are quick, the friction on the side of rails, and the consequent retardation must be very great. This is a point which, till lately, has not been sufficiently attended to...

[Thus] the setting out of curves on the ground is a work requiring considerable skill and exactness (Booth, 1830: 61).

These words were uttered by a Director (Henry Booth) of the Liverpool and Manchester Railway – the first proper railway line to connect two major cities. It opened in 1830, and clearly wheel / rail interaction was a problem that its chief engineer - George Stephenson - had to contend with. Indeed a colleague of his wrote, after conducting numerous experiments on frictional resistance:

There is no subject, perhaps on which there is a greater diversity of opinion, than in the laws which govern friction (Wood, 1838: 388)

Wheel / rail interface problems in other words have always created dilemmas for engineers ever since the idea of placing a metal wheel on a metal rail was put into practise by one Richard Trevithick in 1804 (Garfield, 2002: 66).

George Stephenson is often referred to as the *father of the locomotive*, but in that simple form the statement is untrue.... It was Richard Trevithick who first practically showed... that a steam engine with smooth wheels could be made to travel and haul a load along a smooth track; that it could be driven with wheels on more than one axle coupled together (Robbins 1980: 9).

Trevithick's experiments and inventions included the construction of the engine *Catch-me-who-can*. Trevithick showed off his engine to an intrigued public, however:

After several weeks of running in a circle, at 12 miles an hour, for the amusement of passengers who cared to pay a shilling for the ride, a rail broke and derailed the engine. Unfortunately, for Trevithick, the number of shillings collected prior to the break in the rail, and subsequent derailment, were insufficient to pay for putting the wreckage back together again (Paul, 1975: 323).

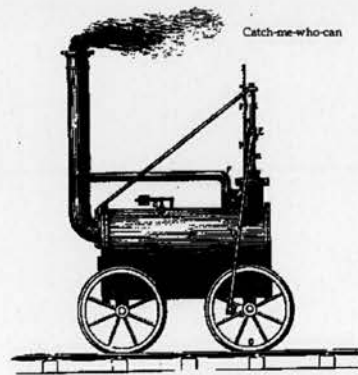
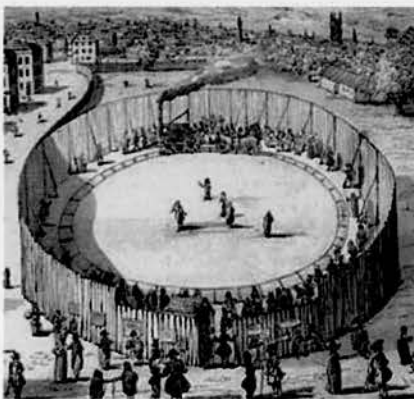


Figure 4-2 Trevithick's *Catch-me-who-can* (Internet source: Spartacus.schoolnet website, 5th August, 2002).

This outcome led Trevithick to confront:

The most fundamental questions of friction and slippage, finding that the weight of the engines alone was enough to ensure good traction in fine weather. But this presented

another dilemma, one that torments engineers to the present day: how to prevent the rails cracking under the colossal new load of moving machines (Garfield, 2002: 66-67).

4.2 RESEARCHING A 200 HUNDRED YEAR OLD PROBLEM TODAY

4.2.1 Elements that are difficult to interpret

The wheel / rail interface still torments engineers today. The increasing frequency of RCF problems and the willingness of many railway undertakings to fund research into its origins and the development of an understanding of its impact are indicators of the interface's complexity.

During their service life, wheels and rails are subjected to a large number of repeated contacts. For instance, a wheel on a passenger coach can travel 200,000-miles per year, equivalent to about 100 million revolutions. Although these contacts are scattered across the width of the wheel tread, a small area on the wheel is still likely to see more than 10-million contacts per year; this cyclically stresses the material through rolling contact (Clark & Dembosky, 2002: Conference paper).

It has been shown that as result of such intensive contact:

The natural processes of wear and deterioration of steel can proceed at a pace that results in long service life, or they can result in rapid condemnation of a rail (IHHA, 2001: 5-54).

Where the wheel / rail interface encourages the shortening of rail life it is also known that the:

Rail surface suffers from failure in the form of wear (detachment of material) and RCF (cracking) (Kapoor, 2002: Conference paper)

The process of deterioration that gives rise to RCF and wear involves the deformation of the rail. The rail:

Accumulates deformation until the ductility of the material fails (Kapoor, 2002: Conference paper).

The Railtrack document RT/PWG/001 (Railtrack, 2001a) described the same process:

In track, the running surface of a rail gets rolled out by the passage of wheels which results in the creation of a zone of residual compressive stress at, and just below the surface (Railtrack, 2001a:12).

Traffic tries to roll out the top surface of the railhead

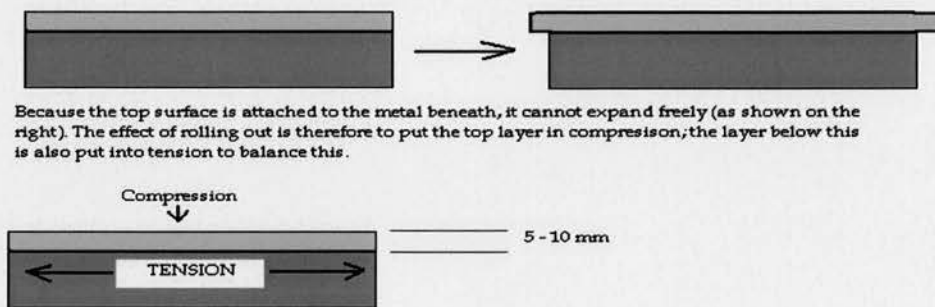


Figure 4-3 Residual Stress Development (source: Railtrack, 2001a:12).

It is also widely accepted that, when under repeated / cyclic stress, as rails necessarily are, two behavioural characteristics can be expected.

Repeated loading of rail steel will lead to either elastic or elastic-plastic behaviour (Kapoor, 2002: Conference paper:).

The former (elastic behaviour) sees the rail returning to the initial state that existed prior to the passage of contact. The latter (elastic-plastic) sees the rail surface stressed beyond the limit where which it could return – this will result in “plastic deformation” (Hiensch et al, 2001: Conference paper). In figures 4-3 and 4-4 the stresses that create the potential for metal movement and plastic deformation are illustrated.

When exposed to a cycle of applied pressure as illustrated above, the metal will fatigue and its fitness-for-purpose will reduce. However, as long as the pressure is applied constantly and equally over a specific time-based period the resulting crack will exhibit a developmental pattern at a constant rate relative to the applied pressure. Developmental patterns of cracking can result from normal steady-state conditions; as such, the developmental patterns become interpreted as normal:

Fatigue crack growth prediction is of prime importance for engineering design. Each cycle during crack growth under certain constant amplitude loading sequence contributes a characteristic and equal crack growth increment to the extension of the crack (Lang, 2000: 588).

When the conditions are steady-state, predictions of crack growth and fatigue over time are feasible.

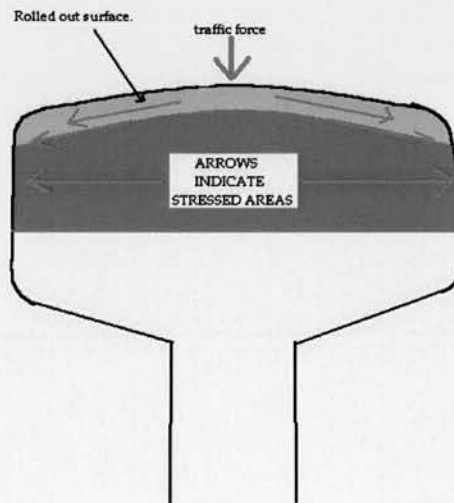


Figure 4-4 Residual stress development. Current thoughts on metal movement of rail (source: Railtrack, 2001a: 12).

4.2.2 A shift in thinking

It was considered that steady-state conditions were inherent at the wheel / rail interface, but recent rail-failure trends (see fig. 4-5) have suggested that there should

be a re-think. During 2000, and before the Hatfield derailment in October of that year, the Office of the Rail Regulator invited the American company TTCI to assess and compile a report of Railtrack's methods for managing broken and defective rails in light of growing rates of rail defects.

Findings told how a specific rail failure type, RCF, is now a major form of rail defect not just for the British network, but for many other railway networks around the world. They wrote:

Three of the major passenger railways report RCF damage (shells and squats – subsets of RCF) as the number one cause of defective rails. This illustrates the rise in RCF damage on high speed railway networks (TTCI, 2000: A-17).

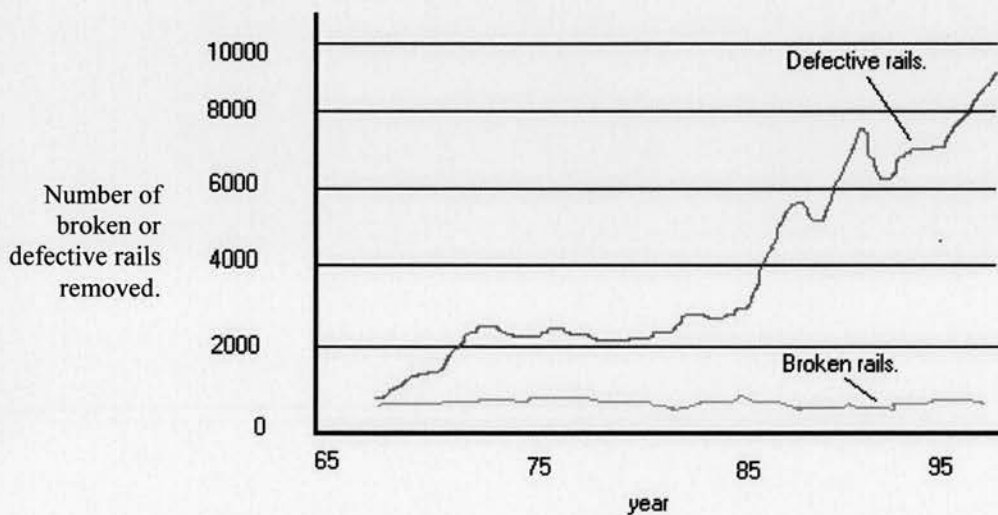


Figure 4-5 Long-term trend of broken and defective rail removed from British network (source: TTCI, 2000: A-9).

As a recommendation for Railtrack, the report's authors said:

Given the growth in numbers of RCF defects (such as squats and gauge corner cracks – both are subsets of RCF) which pose a special safety risk, Railtrack should actively pursue research to gain a better understanding of the way in which the defects form in order to prepare mitigation techniques (A-57).

A consequent development in Britain was the formation of the Wheel / Rail Interface Systems Authority (WRISA). An aim of the authority was the drawing together of all those in the industry (i.e. maintenance companies, vehicle operating companies, infrastructure owner) who have a commercial interest in the quality of the wheel / rail contact spot, as it is widely believed that RCF is a manifestation of the interaction between wheel and rail. A speaker for the authority at a conference said:

RCF is a consequence of operating steel wheels on steel rails – [RCF] will always be present in one form or another (Clementson, 2002a: Conference paper).

He then conceded that there had been a shift in perception that departed from the “steady-state⁴²” school of thought. He claimed that there was an:

Initial belief that RCF was due to steady-state operations and that the conditions were, in effect, designed into the railway. ... But it has become clear that many of the mechanisms leading to RCF are not steady-state (Clementson, 2002a: Conference paper).

Lang did not suggest that steady-state conditions characterised the wheel / rail interface of the railway industry, it seems, however, that this was a common line of thinking: Lang only described the process of metal fatigue from cyclic pressures which are constant and “normal”. The idea that stresses at the wheel / rail interface are “transient” and not “normal” or “constant” marks the shift in perceptions hinted at by Clementson (2002a: Conference paper). It is now thought:

Wheel / rail contact stresses and traction coefficients are both steady-state and transient. Steady-state causes are a consequence of the constraints placed on the engineering design of the railway system such as tight curvature in geographically restricted location. Transient causes are the result of normal vehicle / track degradation or imperfections in the

⁴² As a reminder of what was described on pages 112-3, steady-state conditions refer to conditions that are constant; meaning any cracking and wear will exhibit developmental patterns relative to the pressure applied, enabling prediction of fatigue and crack growth. Transient refers to conditions that are not steady-state, thus predictions of fatigue and crack growth are infeasible.

maintenance of the infrastructure and/or the vehicles (Clark & Dembosky, 2002: Conference paper).

Determining contact stresses and the traction coefficients, for predicting rail lifespan has become the focus of much research. The research problem is characterised by gaining an understanding of the steady-state and transient nature of the stresses (see fig. 4–6), as an example of the likely sources of these stresses) involved at the interface. As Eickhoff (1999) suggests:

The rolling contact of the steel wheel on the steel rail is a phenomenon that is peculiar to railways and is fundamental to an understanding of the behaviour of the railway system. [But] the way in which the forces (that are required to stop and start, support and guide the railway vehicle) are generated and transmitted are highly complex and highly non-linear (Eickhoff, 1999).

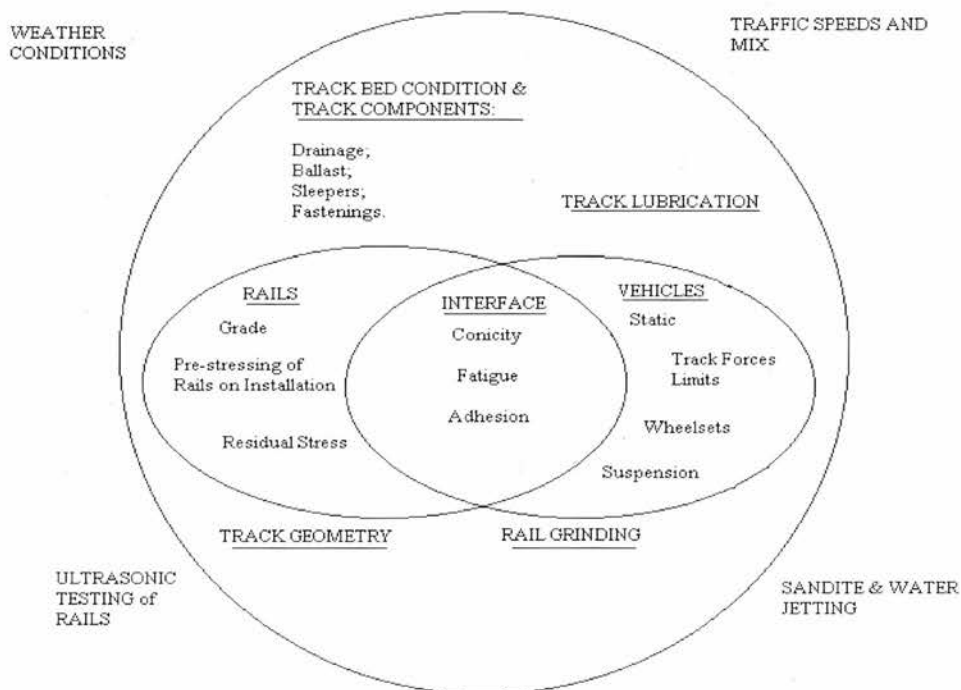


Figure 4-6 System diagram for wheel / rail interface variables (source: Brentnall, 1998).

About figure 4-6, the author tells us: “All the above elements contained within the “wheel / rail dynamics system can have a direct impact on RCF and crack

propagation rates” (Brentnall, 1998: 15). Quite similarly, Eickhoff (2002: Conference paper) suggests that managing the problem of RCF, and ultimately understanding it, is a mammoth task. This is because of the large number of identified influencing variables that are connected to the wheel / rail interface and which pose a problem in the search for an optimal performance of wheel and rail. Eickhoff (2002: Conference paper) lists some of these variables below; the list is not intended to be exhaustive and some factors are intentionally included in both lists.

Vehicle factors

Suspension characteristics.	Wheel material
Loading conditions	Traction and braking characteristics - stopping patterns
Wheel profiles - new and worn	Speed, cant deficiency
Wheel diameter	Lubrication... etc.

Track Factors

Curve radius, cant, gradient	Rail section
Track structure, support stiffness - fastenings, etc	Rail material
Track geometry – design /maintenance Rail profile - new and worn	Speed, cant deficiency
	Lubrication...etc.

Consequently, rail specialists across the globe are concerned with understanding the interaction of these variables. One group of technicians offer the hypothesis:

Once linear and angular wheel-set coordinates, velocities, and forces are known from the vehicle / track interaction, then the magnitude and distribution of normal and tangential stresses, relative slippage (creepage) and friction on the contact patch can be found, provided that the rail and wheel profiles and third body properties are known. The latter is a rail / wheel contact mechanics problem (IHHA, 2001: 3 - 4).

The authors then demonstrate the problem for rail engineers by analysing the wheel / rail interface from two angles. They labelled one: the normal problem, and the other: the tangential problem. To start, they refer to the work of Hertz who:

Presented the first reliable mathematical solution to the normal problem. [The solution Hertz proffered] determine[d] the size and shape of the contact region and the normal contact stress distribution. [Hertz's solution assumed that] two bodies (wheel tread and rail rolling surface) touch at a point. [Thus] the un-deformed distance can be defined if the radius of the curvatures in the region of wheel and rail are the same. [Also] if the bodies are loaded by a normal force, then an elliptic contact area comes into being with a longer semi-axis along the rails longitudinal axes, [and by way of an equation] the maximum contact pressure can be calculated (IHHA, 2001: 3).

But, for Hertz's theory to give a valid reading of normal contact stress on rail and wheel tread surface it has to follow some assumptions such as:

The contacting bodies are homogeneous and isotropic

The contacting surfaces are frictionless

The contacting surfaces are smooth (IHHA, 2001: 3-7/8).

The "normal" problem may be rephrased as the "ideal" problem: where all aspects of the properties of wheel / rail interface are perfectly understood. Yet, there resides the problem and goal for the railway industry.

During vehicle movement the position of the wheel-set in relation to the rails changes considerably resulting in various combinations of wheel / rail contact zones. ... Even for a constant axle load, the normal contact stress distribution varies considerably because of the difference in radii of the curvatures in these regions of the contact.... [Thus] the Hertzian assumption is not valid and a non-Hertzian solution is necessary for predicting the contact patch geometry (IHHA, 2001: 3-7/8).

4.2.3 Examples of current research

Of the railway industry's attempts to gain a non-Hertzian understanding of the problem of wheel / rail mechanics, a respondent told me:

There're a lot of different research activities ongoing at the moment concerning the track. The research is an accumulation of, and mixture of, history, current working practices, new research, new technology and best practice experience (Int: 19).

Given now are just two examples of current research activities.

Example one In a paper presented to an audience at The Institute of Mechanical Engineers, a member of Railtrack discussed the "Wheelchex" programme:

In 1999 the number of broken rails being reported periodically was increasing. In this climate Railtrack committed to a programme of reduction and included within that was the introduction of "Wheelchex" on the network to monitor and address excesses of vertical force as impacts from wheels on rails. ... [U]sers had to be recognised, operators had to be included to complete the system development, procedures for communicating and using the data had to be written, reliability had to be designed in, the costs for maintenance and on going development had to be addressed (Wasserman, 2002: Conference paper).

Clearly, communication, cooperation and, most importantly, feedback between the infrastructure owner (Railtrack) and the personnel from different parties they collaborated with to *create* the programme, were critically important if it was to be successful. The parties included passenger and freight service operators, maintainers, and consultants.

The response from operators and Railtrack zones has varied from initial suspicion to enthusiastic embracing of the information. Most operators have recognised that the output has supplied them both with real information to manage maintenance as well as a means to be compliant with Railway Group Standards (Wasserman, 2002: Conference paper).

During the presentation the danger of non-cooperation between parties was highlighted by illustrating a hazard that hit a similar programme elsewhere:

It is useful to compare this against the experience in Spain where an installation [of Wheelchex] has not progressed any further as the cooperation between operator and infrastructure and supplier did not appear to take place (Wasserman, 2002: Conference paper).

The thrust of the speaker's argument is simple: the introduction of new technology requires explicit cooperation because of the organisational structure of the industry and the nature of the wheel / rail interface. Management of one side of the interface cannot be independent of the other side. A change on one side has to take into account the impact it will have on the other. To be precise: *Network Wide Collaboration Is Essential*:

There has to be an industry-wide response to implementation of condition monitoring because the systems tend to interrelate – the wheel and the rail interface. Real improvements are being made in reducing the number of broken rails, and train operators are also more aware of the consequential damage being caused to their subsystems by poor wheels. These achievements had been made by drawing together of the interested users by Railtrack and AEA, (Wasserman, 2002: Conference paper).

This example emphasised the need for cooperation and exchange of knowledge between the parties at the heart of the industry, i.e., the train operating companies (TOCs) and Railtrack, in the area of rail-condition monitoring.

4.2.4 The need for balance

Continuing this line of enquiry, it was also argued that the industry had to be “joined-up” regarding matters about the wheel and the rail. A member of WRISA told an audience at a regional meeting of the Institute of Mechanical Engineers, that the system had to “be in balance with itself”. To describe what he meant he spoke of historical changes within the industry whilst offering an array of significant examples. He mentioned how “traffic rates are now higher”, and that “traffic is getting heavier”. Underpinning his argument, he gave a simple example as to how traffic is getting heavier in one way, and the effect this has for the track components:

A TOC wishes to have air-conditioning: it's fitted. This puts the weight up, especially as carriages are also longer now. Braking performance is changing: Braking capacities need to be higher as traffic is faster. There have been changes in the track. The track is now stiffer than what it was; due to a change from wooden sleepers to concrete sleepers. The suspension of vehicles is stiffer now than it ever was. Yaw dampers are fixed on all modern vehicles; this affects the vehicle / track interface on curves. Wheels are smaller in diameter now but we are unsure as to the effect that this has (Clementson, 2002b: Conference paper).

The important point is that all these changes have an impact on what happens in the wheel / rail contact patch. The players involved with the development of the components mentioned, must move together. This point was agreed upon by an industry metallurgist:

The problem is the rail is one component in a system, if you're designing a pin for a car, you don't know how it will be used by the operator. Our standards and others' standards are scientifically based, but rolling stock has to be maintained, dampers have to be maintained, springs have to be maintained. Everything has to be maintained exactly then there may be no RCF. The whole thing has to hang together; the problem was that it was split up; there were changes all over the system. After privatisation sales dropped, we then produced 30,000 – 40,000 tonnes of rail, that is enough to cover just .6% of the network, that is estimating a 150 year life span for each rail (Int: 22).

The industry clearly has to move together, and if they do not, one industry worker suggested:

There has been a significant change in the weight of the vehicles, in the speed of the vehicles, that has to have an effect, to give you an example, [name of TOC services] they have motors... they have driven axles... virtually every other axle is driven so the amount of power that you are putting into the rail is quite high and that has an effect. Equally, over the years the amount of investment into the track maintenance has been limited, and things deteriorate. The railways of this country are 150 odd years old so, everything has to come together. Now small changes are the straw that broke the camel's back because you're so at knife's edge (Int: 23).

Elsewhere, others mentioned specific instances of “industry-parts” moving out of sync:

The problem of RCF was highlighted post-Hatfield, but RCF has been documented for the last 20-30 years – it was not a significant problem, but an imbalance was created: rails have remained unchanged over the last 150 years or so, I think the first steel rails, as we know them, were laid here in Derby in... 1857 or so. The chemical composition is pretty much unchanged, but the manufacturing process has changed, tolerances have become tighter, but it is a dated system and the imbalance is using vehicles with higher tractive and braking forces on it. There's been an optimisation of vehicles, but not with rails... I mean rail profiles have been played with, but the same problems remain (Int: 25).

Echoing this, another said:

You can pick on a lot of different areas; they'll all have a contributory effect. Newer vehicles will steer better around corners, and the suspension is better. Whereas before you had vehicles going all over the rail but now there is more focused contact on one area of the rail that is being worn and hardened. Whereas before there is more balance across. Also you've got increased forces, there is a gradual deterioration of the track, which is increasing because of financial cut-backs on the track maintenance. And they're introducing trains with higher traction forces, so it all seems to be contributing to general rail deterioration and RCF (Int: 27a).

Then, through a graphic account of differences that existed between industry members, an industry scientist explained why the different organisations involved in railways and their management must cooperate:

Again, you have to excuse for this because you will always get a personal bias here. My perception of the industry was that it was extremely difficult to get to understand the practical situation of the railway / wheel interface because effectively the guys running the railways said you guys go and do what the hell you like in the laboratories leave us to run the railways, don't come and interfere. So access to the track was very, very limited. What Hatfield did was, if there can be a silver lining to such a catastrophe, make them aware of the potential disaster that can happen. So access to track became a lot easier. So now we are monitoring about 30 different lengths of track regularly (Int: 23).

Functionally effective interaction within the industry is a must, but what of the impact of organisations outside the industry, such as research institutes and companies with railway engineering sectors?

Example two This example is drawn from observations made by two organisations: the Rail Technology Unit of Manchester Metropolitan University; and the firm AEA Technology which has a subsidiary called AEA Technology Rail. Whilst the Manchester Rail Technology Unit gave a solo presentation at one conference I attended, the two organisations gave a joint presentation at a later meeting. I will touch on the work presented at both conferences.

Both organisations dedicate work to furthering knowledge of the wheel / rail interface and problems that arise from changes in its constitution. This is how they perceive their research:

The formation of RCF in rails is due to the combination of contact stress, tangential creep forces and creepage in the wheel / rail contact patch. Most of these parameters cannot be measured directly with current technology. However, the science of railway vehicle dynamics allows us to predict with confidence what the values of these parameters are for a wide range of different conditions. This gives us a valuable insight into the influence of many different factors that affect the incidence of RCF (Evans & Iwnicki, 2002: Conference paper).

These organisations are involved in modelling railway vehicle dynamics as a means of developing knowledge of RCF through computer software. Take for example the approach these organisations took in co-constructing the programme they are involved with:

The first stage in setting up a computer model is to prepare a set of mathematical equations that represent the vehicle dynamics. These are called the equations of motion, and can be prepared automatically by the computer package through a user interface requiring the vehicle parameters to be described (Evans & Iwnicki, 2002: Conference paper).

The two organisations highlight the role of computer packages in the development of RCF understanding: they also acknowledge that they are not alone in constructing programmes as a means of measuring rail condition and predicting rail failure or fatigue:

A number of vehicle dynamics analysis packages have been developed by research institutes and railway administrations around the world. Examples are ADAMS/Rail, Vampire, Gensys, Nucars and Simpack. These packages have often grown out of in-house software tools that were developed to solve specific problems and are thus different in their operation and capability (Evans & Iwnicki, 2002: Conference paper).

The involvement of research institutes and external technological firms shows how a wide arena exists within which RCF knowledge is developed. Knowledge of rail fitness-for-purpose matters is acquired from numerous resources. There is a wide, complex social network of rail condition research, and of this network, it was said:

[Name of technological research company] objective is to provide solutions to railway issues, by bringing together the necessary expertises whether they are within [this wing of the company] or in [the company] as a whole or within universities and other research organisations. So we don't claim to have all the knowledge and we are happy to hold hands and go together with other organisations and universities to ensure that we achieve the solution (Int: 23).

Despite the numerous sources of relevant knowledge, know-how and skills, problems related to the wheel / rail interface remain. In 1984 de Fontgalland said:

The wheel on rail relationship is about steel on steel adhesion and this requires significant attention. Adhesion is to the railway what lift is to aviation. This is a complex notion, which has been the object of numerous research experiments ... but it still include elements that are difficult to interpret (de Fontgalland, 1984: 8).

And some twenty years later Railtrack stated:

The RCF of rails whether manifested as head checking, tongue lipping or squats, is a major problem worldwide. Despite considerable research, the problem is still not fully understood

and to complicate matters there is often a mismatch between laboratory test results and service performance (Railtrack, 2001a: 3).

This point was consolidated elsewhere by rail specialists of the Union of European Railways:

Faced with insufficient knowledge of the growth rates of various defects and large variations in the capability to detect and size smaller flaws, the industry is poorly equipped to apply scientific rich assessments to rail removal practices (Zuber et al, 2002).

Nevertheless:

The eventual aim of research into the understanding of RCF must be to find ways to eliminate, or at least manage the problem in the most cost-effective way (Evans & Iwnicki, 2002: Conference paper).

Cost is of course another important issue in RCF management. Premature rail failure is a major cause of expense for many rail industries: "The total annual cost of the RCF problem in Europe has been estimated to be about \$US 375 million" (International Railway Journal, February, 1997). Evidently, current interpretations of "best-practice" are thus a major area of work for railway industries around the globe:

RCF is an insidious affliction which must be identified, minimised and managed. ... Things can be done to manage the problem and minimise the risk of rail breakage (Railtrack, 2001a: 3).

In view of this statement we now examine those "*things*" that are "*done to manage the problem and minimise the risk of rail breakage*", by analysing how one maintenance company operates.

5 MAINTENANCE AFTER PRIVATISATION – A SINGLE COMPANY PERSPECTIVE

That is what reforms can do on soil that is unprepared... nothing but harm! (Dostoyevsky, (2003: 822).

5.1 HOW ONE MAINTENANCE COMPANY OPERATES

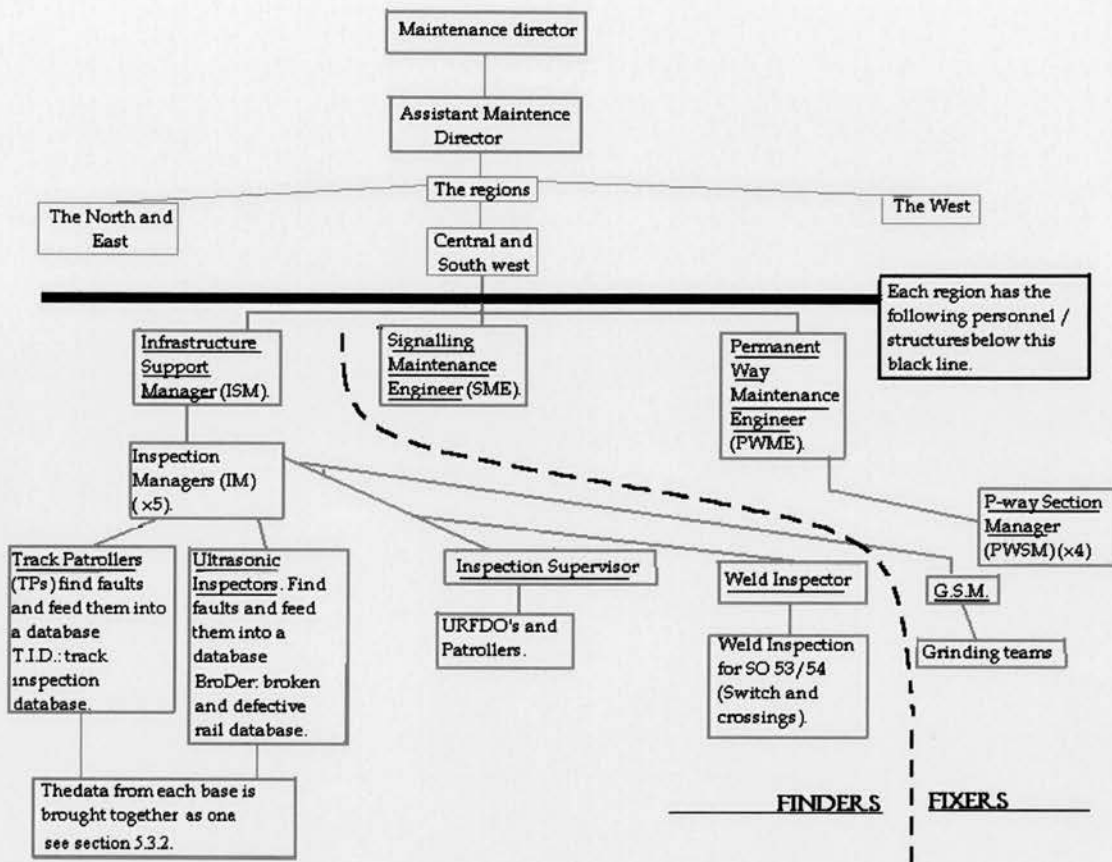
5.1.1 Introduction: the organisation of finding and fixing:

Despite the research that underpins knowledge development of rail problems (as outlined throughout chapter four) a simple idea buttresses RCF management and other maintenance concerns which can be put as thus: rail problems have to be found and then repaired. Track patrollers and ultrasonic operators are the principal finders, whilst manual rail-grinders are the principal fixers. We look at how these occupations slot into the wider organisational spectrum of the maintenance company: we see how these task forces interact with each other in rail fitness-for-purpose management.

The organisational plan of the maintenance company I worked with is given in figure 5-1. Though the illustration refers to how the company is structured for the “Central and South West”, the structure is replicated for other regions: the West, and the North and East. The dashed line highlights clearly how the organisational structure separates the finders and the fixers.

A respondent speaks succinctly about the difference between the two roles:

The overall maintenance in [location] is still run by the finders and the doers. The inspection regime is separated from the doer's organisation. [Name] is running the inspection side, his guys find the faults and the Permanent Way Maintenance Engineer's (PWME) organisation repairs and brings the track back to standard (Int: 02).



it's [an RCF site] gone to severe and we check the gauge corner cracking monitoring and the PWSM is notified. Inspectors don't have the power to impose, but they do advise (Int: 07).

Despite working together closely, the two roles are split quite clearly apart. As such, I now look at each role individually.

5.2 THE FINDERS

5.2.1 Looking for problems

One respondent tells us about the roles of the finders:

Track patrollers are the guys that go out and physically look at the track. They get the data, hand it in or fax it to the database in-putter. ... Track patrollers go along and do the inspection visually, then it's the ultrasonics who do a different type of inspection in more detail (Int: 03).

Another respondent gives a little more detail on this type of work:

We have teams of ultrasonic inspectors and teams of track patrollers whose duty it is to inspect the rail for RCF if possible. I say "if possible" because it is so difficult to identify, especially at night, at the present time most of it is being done and identified at night...we're dictated by Railtrack – we can only get access [to the track] at night. We've come to the conclusion that there is a problem there, because the only way you can be clearly confident is by doing it in daylight. ... We're going through a transition period at the moment from night till day. ... At present, 75% of the route we patrol is by the road / rail Land Rover. But S&Cs [switches and crossings] are done on foot. In the Land Rover at night in artificial lighting you have very little chance of finding RCF. ... The lighting can be like at a football ground but in that environment it's still very difficult to identify the stuff, and all it is, is an operator that drives the vehicle and a patroller for each rail (Int: 02).

It is explained throughout chapter six how searching for RCF is not a simple task as many variables must be taken into account during the procedure, which requires a significant degree of know-how. Because of this the maintenance company decided to cut the variables by limiting the set of people who can confirm RCF sites.

The only people who can clearly classify and mark RCF now are the ultrasonic operators (Int: 02).

This is because:

We can all go out [onto the permanent way] and think we see something, so we have to ultrasonically test... so in all cases of RCF the ultrasonics have to go to it anyway so it was an automatic decision to make them the people who measure it and categorise it. And this way hopefully we don't have so many variables from different individuals... cause anyone out on the railways can find RCF, or think they find RCF so that's why we decided that it was the ultrasonic operators... because they would be there on every occasion. There're so many variables, they would be there in all occasions, moonlight, wet, dry, so it was thought: get these people to understand what all these variables are, and to look at it from different directions and all the rest of it. We were trying be more standardised (Int: 03).

Another said of this standardising process:

I've been at five conferences since Hatfield where the issues have been debated but at the end of the day, what do you do? We have to respond to Hatfield. ... Anyone can do it visually... at [this maintenance company] we decided that it would be the ultrasonic operators but other maintenance companies you'll find there are a variety of people looking for RCF. But we went down the route of trying to produce a group of individuals [for the task of identifying RCF] ... we just decided to do it this way (Int: 06).

5.2.2 Ultrasonic teams

The structure of the ultrasonic teams within the maintenance company however, has been refined still further. The maintenance company's network zone⁴³ is broken into regions, and regional teams are made up of three or four men, including a supervisor. Of the three teams two are concerned specifically with "annual planning" (Fw: 10).

⁴³ Zones – At the time of research the British network was split into seven zones. This maintenance company was the major IMC of one zone.

The other team is only concerned with testing and retesting new and known RCF sites. What this means in terms of ultrasonic inspection of a rail with RCF was sketched out by a respondent. I have re-done the sketch below in figure 5-2:

As a category one line the length of 54 miles is inspected every 6 months, now on top of that 6 month frequency the severe sites are tested (ultrasonically) every 4 weeks, the heavy sites every 8 weeks, moderate sites every three months, and lights sites every 6 months. So the whole route has a laid down inspection frequency and where sites have been identified you have additional frequencies.

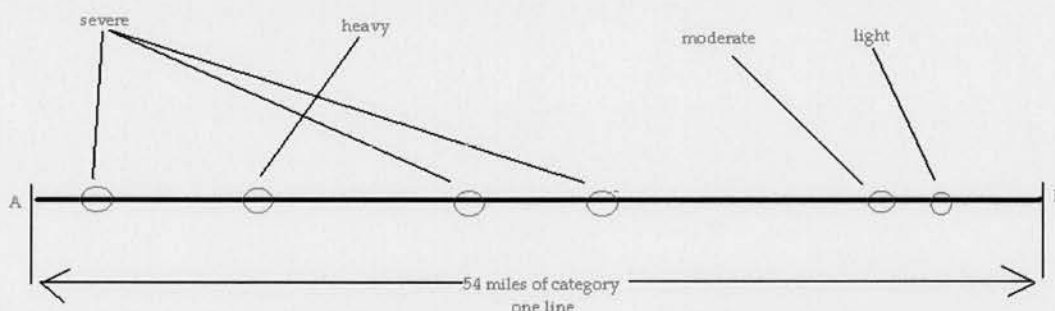


Figure 5-2 Adapted from sketch by respondent in Int: 02.

Despite this anybody on the track that spots RCF must report it:

Anybody who walks and inspects the track has a duty to identify RCF if they see any sites (Int: 02)

And whatever is found has to be examined by an ultrasonic team:

[RCF problems] can be found by track patrollers and track inspectors, but it's been decided that the ultrasonics are the guys who are trained to verify the length of the crack (Int: 07).

A specially developed rail-based ultrasonic testing vehicle is also used on the network. The UTU (ultrasonic testing unit), of which there was only one until recently, was marshalled by Railtrack. About it, one UT worker said:

Railtrack operates the UTU, a train that runs up and down the network that finds defects. Now when it finds a defect it is meant to spray paint on it [on the rail where the fault is], for us to know where it is when we go to look at it. We get paper work that tells where [the fault] is. I

have to take guys off planned work for this... it's not a great disruption.... But there's not always paint, we can't confirm the defect, and out of say, 15 defects three to four are actionable [that's where the UT indicated there was a fault]. And the other 12? It's a waste of time... (Int: 04).

Likewise, a UT operator said:

You can't beat the guys on the ground, we're walking it, surely we'll find the faults. The UTU is fast... but you wonder about it's accuracy, and we have to check all the faults it finds – Railtrack and now Network Rail continue to use it... what can we do? (Fw: 02).

These words echo those of another:

Rail inspection is being developed; since RCF mushroomed you have a number of different companies trying to develop different methods. ... There used to be a lot of walking the track, manual inspection. Manual non-destructive tests [NDT] ... NDTs were always done, but now, because of access problems it has to be done quicker... But doing it quicker, are you always going to pick up all the faults? Even now they have a train that picks up faults but they're still checking them manually, because there are questions about reliability of the UTU because of the speed, and that's because of limited track availability (Int: 27b).

Consolidating this view are these published words:

During the 1990s, ultrasonic testing of the track focused on hand-held equipment, in part due to the unreliable results from the UTU (Modern Railways, March: 2002).

5.3 THE FIXERS

5.3.1 Grinding the rail

The grinding of rails is a basic means of maintaining rails in switches and crossings ... Recent experience has shown that rail grinding is one of the primary means of removing and managing RCF cracks (Railtrack, 2001b:3).

Once found, a problem has to be treated. In terms of RCF, when there are occurrences of it at switches and crossings (S&Cs), manually grinding the rail is the commonly

used practice on the British network as it is thought to be more economic than replacing a whole S&C (Int: 28). For lengths of plain rail⁴⁴ grinding stones attached to the bottom of a specially designed train are used to remove shallow cracking. However, the design of switches and crossings means it is impossible for a grinding train to operate over them; therefore, rail-grinding must be done manually by specially trained teams.

Grinders are typically split into teams of three and a grinding supervisory manager. Each team usually works in a region of the zone whilst the train-based grinding vehicle operates over the entire network:

We have teams of hand-grinders that do it manually at switches and crossings. ... Railtrack have got from the States two 64 stone grinding trains which are running up and down the network skimming and re-profiling the gauge corner.. we had one just a couple of weeks ago. ... There are two grinding trains for the entire British network, there's another... one... or two... on its way... don't know the timescale [of them arriving in Britain].. But this [organisation of train-based grinding] is done by Railtrack themselves. ... The database that Railtrack have dictates where the grinding train goes, we don't have any say (Int: 02).

5.3.2 The RCF manager, databases, and paper-chains

For the management of RCF, the finders and the fixers require an intermediary, and considering the growth of RCF as a problem (see chapter four, page 114) the maintenance company created the position of RCF manager:

The Inspection Manager [once] encompassed all track inspection not just for RCF; RCF was managed in that role. But the problem was that RCF was becoming such a big beast and we were struggling to keep on top of it, so it was decided to bring in an RCF manager. ... The RCF manager's role is still in its infancy at the moment, we don't have all the resources in place for the renewal side of things and the organisational side of it (Int: 02).

⁴⁴ That is a normal length of rail where there are no S&Cs.

Whilst another said:

The role of the RCF manager is combining the finders and the fixers but only on RCF matters. [The RCF manager] oversees the finders and the doers, so [the RCF manager is] bringing the roles together under one banner (Int: 02).

The process of finding and fixing problems can be understood through an account of the paperwork and computer software that the RCF manager works with. During the research period, the maintenance company I worked with had three databases: A, B, and C⁴⁵. “A” recorded all problems associated with all track and rail defects, and “B” dealt with RCF alone.

Individual maintenance companies developed their own software and databases, the consequences of which meant:

There is a lot of duplication... I mean, you have one maintenance company who has developed one rail defect database for their little bit of the network, and then further up the track there is another maintenance company with their own database... you know. It might be a different software package and they don't talk to each other. So these are problems we're faced with and Network Rail has to get control of that. Get all these organisations together and have a two-way flow. You can't have like... the left hand doing something and the right hand doing something different (Int: 27a).

The maintenance company I worked with developed their system in partnership with Railtrack:

⁴⁵Databases A and B are due to be amalgamated and brought into one system: system C. I cannot give the actual names of the databases as this could identify the IMC. Indeed as RT/CE/S/103 (Railtrack, 2001c) Track Inspection Requirements states: “Reporting of broken and defective rails in running lines shall be undertaken using Railtrack approved systems”.

It's [the software system] a Railtrack and [name of maintenance company] driven system. Railtrack can check what we're putting into the system... which is the way it should be, it's their infrastructure (Int: 07).

The computer software and paperwork form quite a complex system within which RCF and other rail maintenance issues are managed. To describe the system it is best to outline it step-by-step through a selection of quotes.

5.3.3 The long and winding paper trail

The track patrollers go out [on to sites with an A1 form and] with a list of defects say between [mileage], and then if they find a new [RCF] defect they report it is as a new site [on an A2 form] (Int: 08).

A2 is only for RCF (Int: 08).

The track patrollers put their findings into a database [A]. As well as finding faults in the first place they also check faults after they have been repaired to make sure they have been repaired meaningfully. Wet-beds are a good example. Perhaps a wet-bed has been dried out, so it looks like it has been repaired, but then the following day it rains and it floods again at the same point, that means it has not been repaired in its entirety (Int: 01).

So it's all fed into this one database, given a unique number and it is fed into [database C], which has got a planning part, a management part and the work is prioritised by the section manager and permanent way maintenance engineer and it is given a date (Int: 06).

Every three months the Section Manager walks his route armed with the data fed into [Database C] to see that the work has been processed. On top of that the Maintenance Engineer walks the same route every six months to see that the regime is working properly (Int: 01).

The permanent way section manager actions Form B [form B is for all defects, including RCF] and actions it within 13 weeks, seven days... [depending on the severity]... This is handed to the database [A] operator and it goes into [database C]. The permanent way section manager plans

the renewal and attaches C1 [which is only for RCF faults. He attaches it only, he doesn't complete the form C1] (Int: 08).

So with a Form B, once it's been repaired the Section Manager has to fill in [a small section of the] C1 to say the defect has been removed so you have two [forms] telling you that the fault has been removed. C1 is what the Section Manager puts in with an RCF faults. What happens is, whoever repairs the fault [the respondent names three maintenance and renewal companies], they fill in the C1 form and give it to Railtrack. Railtrack gives it to us and we go out and check that the faults been removed with the A2 form. So the C1 form is for the contractor who removed the fault. But we don't take it out of our system until we've checked it. But Railtrack don't rely on that alone, they wait on the A2 back from us as well (Int: 07).

Sources of material are brought into this, the work is carried out. If the work is completed successfully and on time then it is fed back through the circle to [database A] (Int: 06).

Ultrasonic operators report their [RCF] findings by putting them into [Database B]. ...The rail is given a reference number, by doing this, whoever has access to the database can see when the fault was found, where it is, the category of the track, its inspection history, when it is scheduled to be worked on and what checks have been made afterwards. There is a paper trail of all the work and the inspection that has been done on any defect, it records who done what (Int: 01).

After it's [RCF] found, prior to any input into the system (B) , the Inspection manager checks it and asterisks anything he wants to question (Int: 08).

The A2 form is given to [name, and they] update the [database B] system and [then the A2 form] is given to the inspection supervisor, who records and programmes it [on paper]. If the inspection supervisor makes a mistake the system highlights it in red and [name] brings it to the attention of [the inspection supervisor] (Int: 08).

We double check all the time; keep all things on paper in case the computers crash. And we do gauge corner cracking monitoring every week. We just monitor anything that changes category so that we know and that the permanent way section manager and permanent way maintenance engineer know (Int: 07).

If a defect is removed it is classed as historical, but not RCF. RCF never comes historical⁴⁶, even after it is renewed. There is an inspection frequency for it (Int: 02)

5.4 WHY THIS MAINTENANCE COMPANY WORKS THE WAY IT DOES

5.4.1 Paperwork Standards, regulations, specifications

A key reason for such a complex system is because of the “Permanent Way Special Instruction 4 (PWSI4) – Management of RCF”. Railtrack stated in it:

Where sites have been identified with RCF or have been re-railed or ground, as part of the treatment of RCF, records shall be maintained for all visual and ultrasonic examinations (Railtrack, 2002, PWSI4-2, 6.6).

Therefore the finding and fixing system is:

A laid down process which is worked around standards. Anything out-with the standard is done by Railtrack and signed off by Railtrack engineers. It's a complex system but quite a strict system (Int: 02).

The paper-chain illustrated in the last section depicts a trend which has increased significantly in recent times:

It's a paper industry now (*Fw: 12*)...

said one railwayman, whilst another stated:

⁴⁶ Quite simply, a rail that has had, at any time in its lifespan, RCF, will always be classed as an RCF site. RCF, it is commonly thought “comes back”, even after treatment such as grinding – there is more on this topic later.

In the past you would look at the track and give it a points system, this was counterchecked by senior managers. ...Now? The whole concept of engineers has changed... engineers are now administrators... oh, there's a lot of paper work... now everyone has a data bank, emails getting sent everywhere with new and more instructions (*Fw: 09*).

By issuing this instruction (PWSI4) Railtrack added to an instruction-based portfolio.

5.4.2 The impact of history

Railtrack and maintenance companies have to work to Railway Group Standards (RGS), which were produced by the Safety and Standards Directorate⁴⁷. This directorate was erected during the Organising for Quality programme (see chapter three: 3.3.1 page 98) and, to flush out inefficiencies and to gain control from a central base, the body developed some 20,000 standards and procedures; 4,000 of which were considered mandatory operational and engineering requirements (Gourvish, 2002: 428), which are:

Technical standards with which railway assets (or equipment used on or as part of railway assets) must conform, and operating and management procedures with which all operators of railway assets, including the infrastructure controller, must comply (Railway Safety and Standards Board, 2004) (This quote is identical to a passage that was printed and published by Railtrack, 1998a: GA/RT6001: 4).

To comply with RGS, Railtrack and maintenance companies had to become a member of the “railway group”, and to do so both had to submit a safety case⁴⁸. Once accepted

⁴⁷ This directorate was originally intended to be an independent body, but later became the safety wing of Railtrack. Through time it became Railway Safety and Standards Board (RSSB).

⁴⁸ Infrastructure operators and train operators must “submit suitable and sufficient safety cases to the health and safety executive for acceptance, prior to the conduct of railway operations. ... [The argument for the safety case is

by Her Majesty's Rail Inspectorate, Railtrack could start to function. To fulfil its obligations in terms of managing the permanent way, Railtrack released specifications such as these:

RT/CE/S/103 Track Inspection Requirements (Railtrack, 2001c)

RT/CE/S/057 Rail Failure Handbook (Railtrack, 2001d)

RT/CE/S/104 Track Maintenance Requirements (Railtrack, 2000)

RT/CE/S/055 Rail Testing: Ultrasonic Procedures (Railtrack, 1998b).

As the foreword to one of the specifications points out:

This is one of a group of four high level Railtrack specifications which are intended to respond to Railway Group Standard GC/RM5600 (Railtrack, 2001c: 4)⁴⁹.

strengthened if it] "demonstrates control of risk the reflects of goes beyond relevant good practice; includes significant improvements to the RSC or control methods from previous submissions or; where new control measures, etc, clearly reduce risks" (Safety Case Assessment Manual, pages 1 & 37, internet source: HSE website 2nd April 2002)

Railtrack's safety case was assessed by Her Majesty's Railway Inspectorate (HMRI). The HMRI is part of the Health and Safety Executive, and by accepting the RSC of Railtrack HMRI was satisfied that the HSE would thusly be satisfied (Safety Case Assessment Manual pages 1 & 4: internet source: HSE website 2nd April 2002). Once accepted by HMRI Railtrack was admitted to the Railway Group. Now, there is a slight difference in how maintenance companies become a member of the Railway Group. Their safety case through time would be assessed by Railtrack, which was fulfilling its role as network controller (Gourvish, 2002: 428).

⁴⁹ Other group standards Railtrack had to comply with include these two for instance:

GC/RT5022 (Railtrack, 2002b) Rails and Rail Joints, the synopsis of which points out: "This document ensures the safe performance of the, track system by specifying requirements for rails and rail joints and for their inspection. It also lays down requirements for minimum actions to restore safety when broken, cracked or defective rails and rail joints are found."

GC/RT5023 (Railtrack, 1999) Categorisation of Track: "This standard sets out the procedure for categorising track in running lines by usage and speed, so that requirements relating to design, maintenance and renewal and inspection of the track may be specified and applied."

In complying with RGS, Railtrack issued many specifications which the maintenance companies had to adhere to, as set down in contractual agreements:

The line specification or group standard is issued to us through a variation of instructions through the contract that we are duty bound to follow. You can't just bring in a group standard, or a specification, there is always a ramping up period. It's got to be briefed out, the guys have got to understand it, it's very difficult (Int: 06).

Another similarly pointed out:

It's not just a matter of that's what you work with; there's a lot of debate, it can take a document over a year to get passed down. There's a lot of debate, to-ing and fro-ing... It's because, to increase your inspection you have to increase your staff levels and increase your access levels, the staff levels have got an immediate impact on the core budget because you've only got a set amount of people, and you need to bring in technically qualified people, competent people. You can't just bring someone of the street and say tomorrow you're looking after RCF; it just doesn't work that way. There're a lot of contractual things that can prevent best practice coming through (Int: 07).

5.4.3 PWSI4 Issue 1, PWSI4 Issue 2, PWSI4 Issue 3...

This is the contract climate within which the document PWSI4 Issue 1 (Railtrack, 2001e) was released, and of its release I was told

After Hatfield Railtrack issued Special Instructions which we had to act on, they included instructions on inspection. The initial inspection was the total walk of the route by senior managers. But at that point because it was a relatively new defect a lot of people walking it didn't know what they were looking for... That exercise was done over the 6 weeks immediately after Hatfield... As a result of this Railtrack issued amendments to the Line Standards, and called it PWSI which means permanent way special instruction. And from this they defined what they identified as RCF, and what the inspection frequencies should be for both ultrasonic testing and visual inspection... And what the minimum actions should be from the inspections.... We are currently working to PWSI 4 issue one (Int: 02).

It will be noted that the PWSI4 was referred to as Issue 1, this is because at the time of that interview *Issue two* had been released by Railtrack; and in April 2003 *Issue three* was released by Network Rail. The rapid release of these issues is because of increased RCF-knowledge, for instance:

This instruction contains changes to previous requirements. These result from increased knowledge on the types of RCF, advice from world experts and analysis of data (Railtrack, 2002: 2.2).

Despite gains in knowledge, the rapid release of these documents created some problems:

The difficulty was that [issue one] contained a lot of technical errors; it came out in haste following Hatfield but because it contained technical errors and confusion in some parts issue 2 came up very quickly. Certainly issue one did allow for engineer's judgement but because it was abused... more extreme than expected, issue 2 came out very quickly... which was all about "shall do in accordance..." and issue 3 as far as I am aware is not any different (Int: 03).

Nevertheless, problems remain:

Anyone on the track doing visual checking can report something: the section manager can report something; Railtrack people can be on the track and find something and report it; the UTU [Ultrasonic Testing Unit] finds things; and your track patrollers... and these can report things and the problem is, is it's not all standardised. There's a problem of people not working to the same standard... and people's terminology can be different. Even location [of RCF defect] can be unclear! (Int: 05).

5.4.4 Spray paint marks the spot

In this section we have a brief look at the problems of location of an RCF problem. To start, let us take the following excerpt from a monologue that took place during some fieldwork where the railway man I was with had to inspect two separate sites. Now what needs to be known is that a defect's location on the rail itself is labelled by paint on the sleeper and web of the rail. Also, according to PWSI4, sites must be 18 metres apart (defects within that distance are classified as the same site).

I notice that the two sites that Alan (false name) has checked are side by side. One though is long and covers several yards, whereas the other is only three yards long. But why are they not all classed as one site as they are definitely not 18 metres apart?

Alan explains: what happened here was that someone came out and spotted the first site, it was so many yards long; recorded it, and it got its own [code for a database]. Then someone else came out later, spotted this site [the one we are at now], 'but it's part of a switch and crossing and the other site is continuously welded rail. You can't put it down as all the same, because it could come up as a renewal site. The [renewal] guys come out expecting it to be continuously welded rail, but it's a switch and crossing also and they don't have a set, it has to be ordered, so it has to be different. It can be confusing though because you can see all the paint on the sleepers and the rails. The guys will come out and think... what's going on here?' And the problem gets worse when guys come out and go by their own mileage, because then you get more paint and more locations that should be one and the same. "As soon as it is fed into [the database] everyone should work from that mileage but people don't. They stride it out themselves and come to different conclusions". So this problem with sites so many yards apart is a problem that PWSI4s don't address; 'It can be confusing. I had a disagreement the other day about where a site was because of the wording in the PWSI, you can take some instructions two ways' (Fw: 11).

Offering an explanation for this confusion I was told:

An RCF site is the length of rail from the first occurrence of RCF to the last. Sites must be 18 metres (or 50ft apart). But there are no markers to give you the exact distance, some should be there but have gone; vandals have taken them and they have not been replaced. So one's 50ft could be different from another's. You can mark it out by pacing, but then the short man's 50ft is different from the tall man's. And then in the site you have to mark the longest crack by painting a mark on the rail web. Railtrack now wants all crack lengths marked individually, that's a lot of paint on the web, and with the grease it gets dirty... and grease from the lubricators can hide crack and propagate cracks... And then one track patroller can see a crack longer than the last track patroller and he puts on a new mark, and so on, it can all get confusing (Int: 01).

Despite these problems, confusion was intended to be cleared up by the PWSI4s in one area, namely terminology when referring to RCF.

5.5 NAMING THE BEAST

5.5.1 Defining a problem

The PWSI4s (issues one to three) are more than a mere instruction on how to manage a problem. Railtrack – also “defined what they identified as RCF” (Int: 02). This is because the term RCF has a curious history.

In a 1974 project commissioned by the British Railways Board Research and Development Division, RCF was described as a “phenomenon ... which has received very little attention in the past”⁵⁰. Then curiously enough, ten years later in 1984, British Railways Board issued the document “Rail Failures: description, classification, and reporting”, in this document the term RCF (and its subtypes i.e. gauge corner cracking) do not exist. Twenty years later in the Railtrack documents: Rail Failure Handbook (2001d) and of course in the Railtrack PWSI4s the RCF acronym reappears. In the PWSI4 (all issues) the: “Classification of Types of RCF” is shown; areas of the rail head are divided into regions, denoting where each type of RCF occurs (fig. 5-3).

Given RCF’s historical - documentary - “absence” steps were taken to ensure all relevant persons now share the same language and terms when talking about the

⁵⁰ The project was commissioned by British Railways Board (1974): Research and Development Division, Track Group (Internal Memorandum IM FM 57). The project was titled “A Preliminary Investigation of RCF”, and was completed by Mr R. J. Allen.,

problem, but members of the industry past and present have a range of views concerning RCF's historical "existence". "It's been around for years" (Int: 21) and "it's a new phenomenon"⁵¹ (Fw: 07), are two quotes that categorise the dominant views. This is why Railtrack had to provide a clear definition of the problem:

Gauge corner cracking and RCF? It's new by name. Before the Speno, [see glossary -train fitted with grinding stones] took it away before it got out of hand. There's more shock associated with it now because it was only associated with curves, but now it's everywhere (Int: 08).

Furthermore, an ultrasonic operator gives his thoughts on the role of terminology since industry leaders pursued the "RCF" problem:

It used to be just head checking and then gauge corner cracking because it was on the gauge corner. But over the last couple of years it's all called RCF; this includes false flange damage [see glossary] (Int: 07).

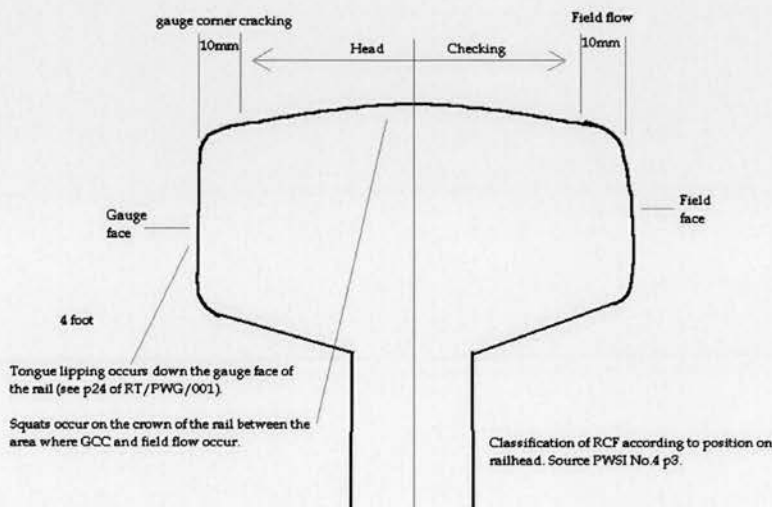


Figure 5-3 Denoting where RCF subtypes occur on the rail head (source: Railtrack, 2001e).

⁵¹ RCF was indeed described as a "recent phenomenon" at an industry conference also. The speaker also said that the railway industry should seek to "contain the phenomenon... and to develop an understanding of the phenomenon and its causes" (Higton, 2002: Conference paper).

Similarly other railway workers told me:

[RCF] has been around for years, well gauge corner cracking has been around for years, then it was head checking. Now it's all called RCF (Int: 21).

Before Hatfield it was not RCF, it was gauge corner cracking, but it became a bad name, it was in the news all the time, the media was looking to use it, so it was decided to call it RCF, it's just the same (Fw: 02).

RCF wasn't highlighted until Hatfield. It was known about, but it wasn't seen as a problem. I was with the Track Renewal Division when Hatfield happened, and three days later, there were speed restrictions all over the [West Coast Main Line] WCML. RCF was all over the line, it had always been there, but now there were 20mph speed restrictions everywhere (Fw: 18).

Then, in response to the question, whether RCF is more common today than it was 10 to 20 years ago, an industry metallurgist told me:

It is difficult to say yes or no to that. RCF has been there for a long, long time, but the consequences of RCF are far more serious today as it can develop into a defect like that [he pointed to his computer screen where he had downloaded an image of what looks to me a very bad case of RCF which has caused a rail fracture] which can break. Whereas previously it appeared as cracks on the surface; some of which had developed over a longer period of time because the traffic was less and axle loads were less and so on. But it did not manifest itself into a huge safety risk (Int: 22).

Another worker told me how perceptions of RCF used to be different to what they are now:

Years ago, about '91-'92, when I was working down in London, I came across it, the guys I was with were asking "what's that?" "What's that?" And the guys from that area said, "Oh, that's nothing"... Then rails starting breaking, and it came to a head with Hatfield. ...But with that, everyone started worrying about the surface, but what's underneath? That's what I'm worried about (Fw: 16).

Likewise another said, in response to my question, whether RCF is new:

It was basically head checking [see glossary] and no-one really paid attention to it, no-one thought about its repercussions, no-one thought that Hatfield would ever happen. It's just that... it's really jumped forward since then... maybe if you look at the rail make-up as well, maybe it's poor quality rail, I don't know, maybe the metals too soft. Maybe the train operating companies should have a look at the quality of their wheels, I don't know, it's like a disease (Int: 07).

The men I spoke to suggest there has been a shift in the "status" of the problem; it has indeed become "a big beast". In October 2000, just days before the Hatfield disaster, a report into Railtrack's methods for managing broken and defective rails was released. It was completed by transport specialists (TTCI), and commissioned by the Office of the Rail Regulator in light of an increase in broken rails across the network.

The report said Railtrack and two other "major passenger railways [that took part in the study] report RCF damage as the number one cause of defective rails". Whilst elsewhere, it stated: "RCF damage (squats [see glossary], gauge corner cracks, head checks) on the rail has increased on Railtrack over the last few years" (TTCI, 2000: A-17 & 51).

The shift in terminology appears to accommodate the burgeoning problem. Take these words of an industry welder, for instance:

I've been in the industry for 25 years and it's always been there, it's not new. It's because of work hardening. ...RCF was found at crossings but we didn't pay much attention to it, because it was just "cracks" it wasn't called RCF. There was the Speno train that used to operate over the network grinding it out. Grinding was done before Hatfield; we regularly removed lipping [see glossary] by grinding and if there was a crack you dug it out and repaired it, it was good practice and it was an ongoing programme. But it was Hatfield, then the shit hit the fan. ...The cause of that crash was not RCF, the cause of the crash was because it was not removed, it was the maintenance standards that caused the crash. ...But Hatfield happened and people were panicking... it was pure panic, we walked hundreds of miles of track being told to look for RCF, and we're asking: What's RCF? What's gauge corner cracking? So people just didn't know what they were looking for and noted everything. Then the first time I saw it, I was out walking with a guy from Railtrack and he pointed it out to me

and told me: "That's RCF". I thought that's "shelling" [see glossary]! I've repaired that thousands of times! (Int: 28).

Elsewhere, a professional engineer addresses an audience at a railway industry conference. Whilst discussing RCF's increased frequency he refers to the development of RCF terminology:

Railway engineers have been aware of transverse cracks across the rail head, what would now be classified as gauge corner cracking, for some time, though it is generally considered that the occurrence of this type of defect has increased in recent years (Wright, 2002: Conference paper).

The stand-out line is this: "Transverse cracks across the rail head, what would now be classified as gauge corner cracking". RCF has always been a "problem": recall Trevithick's problems in chapter four (4.1.2 page 110), yet now it is commonly seen as a serious problem, and for this reason it is no longer "funny flaking" (Int: 18), or "shelling" (Int: 28). It has been verbally recast. PWSI4 constructed a definition of a problem into a common vernacular for all who mattered – the role of precise terms and labels was now critical.

The rise in RCF as a major problem also led to a change in the technical specifications of rail. Industry leaders decided to halt the use of a particular rail-type after the Hatfield derailment. A senior metallurgist at a manufacturing plant where rail is produced for the British railway network, told me:

After Hatfield Railtrack stopped ordering heat treated rail immediately, but we were still selling it to SNCF, Swiss Rail, to the Dutch, to America, Belgium.... the industry at large adopted heat treated rail. The heat treatment plant [at this site] has not been used since Hatfield. Just before Hatfield, [this plant] almost halved its work force and reduced its output from 10 to 5 shifts working with the intention of concentrating on the home market with about 10/15% export. Before, [this plant] exported up to 75% of its produce. In the 75% export there was some heat treated (HT) rails. Since Hatfield [this plant] has not produced HT for Railtrack but there was about 1000 tonnes of HT on stock for the home market which is being used up. ... After the Hatfield derailment Railtrack decided they didn't want this "new grade", it wasn't

new they'd been using it for 20 years. Before Hatfield we knew about RCF, 10 years ago we gave seminars in Latvia and elsewhere advising: "don't move to hard rail as standard" as they didn't have the management structure in place (Int: 22).

5.6 COMMUNICATION ISSUES: A TWO-WAY PROCESS?

5.6.1 The Wheel / Rail Interface: the organisational meeting point

We now look at the communication process between Railtrack and the IMC by using two subject areas as heuristic devices to assess the quality of this process. Firstly, RCF is commonly accepted as a wheel / rail interface problem. Given this, what forms of communication are there between the maintenance companies, the train operating companies, and Railtrack? Secondly, in the privatised climate there are numerous private companies that all require access to the track: how is this organised?

So to the first point regarding the wheel / rail interface. One engineer gave me a brief historical glimpse when I asked: what interaction is there between the IMC and train operating companies then, because wheel profiles presumably have an impact?

Well, in the past there were the British Rail rolling stock engineers and British Rail approved wheel profiles. Now... Railtrack still approve the wheel profiles of the train operating companies... We knew the wheel profiles in BR days... Now?... [Name of TOC]... wheel profiles come from an Italian company... I think (Int: 05).

Another confirmed the hesitant words of the last speaker after I asked the same question:

None, no interaction... Railtrack seem more focused on rail profiles than wheel profiles (Int: 02).

And when I asked another about Railtrack's intermediary role between the IMCs and train operating companies, the respondent at first said nothing but then made a *zero*

with his thumb and forefinger and shook his head negatively. But when pressed, he did eventually say:

There is a forum of the area delivery group which is attended by contract directors of the maintenance division. Railtrack chairs this and [representatives of train operating companies] attend... as far as train companies are concerned... I would suggest that they think of it as a rail maintenance problem. But there are various thoughts that changing wheel profiles doesn't help matters over the years. These are my thoughts! (Int: 06).

So what about the gaining access to the track?

5.6.2 Possessions

When work has to be done on the track the maintenance company has to gain possession of the relevant section of track. Possessions are slots of time when no traffic will operate over the track that is to be maintained or renewed. Planning is therefore a key process, and of this, one worker said:

Applying for possessions is a logistical nightmare (Int: 05).

This is why:

Well, train operators want to run trains: that's what the track is there for, to move people. The less time you have trains running on it, the less income you have. There is a need for a balance, to get enough possessions so that you can be sure the track is in safe condition but not restricting access so people can't move around. So all the developments in the industry are to try and get things done quicker, and done in a smaller possession time, and doing it when people don't want to travel, which is in the middle of the night (Int: 27).

Once, when I accompanied a worker who completed a single ultrasonic test during the day, it became clear to me why most work is done at night:

It's difficult, it's not done during the day, there's just too much traffic... how long was that between [name of TOC] and [name of different TOC]... five minutes?... So you only get time

at night, and then you've got problems of light, it is easier to see [RCF] during the day... (Int: 05).

I had a discussion with another industry worker on the same issue:

R: ... the biggest thing in inspection at the moment is access and getting possession, everyone has to be safe. And RCF at the moment is done in a red zone⁵² where we need lookouts, so that's a problem when looking for new sites. ... They're changing it; all the detection of RCF at the moment is done in red zones. Now they want all RCF done during green zone so that's moving to nightshift.

I: How much input do you have in these changes?

R: Not as much as we would like to have... the central planning area deals with all our possession requests, but when it comes to technical things like why we need daylight, we're not getting it, the train companies would not allow it. Cause it disrupts the travelling for the public. Work on the railways has always been done during the hours of darkness (Int: 07).

Moving work to night-time does not solve all problems: instead it can create problems as it makes that time of day extremely busy with railway workers almost jostling for access to the track:

You could have a possession from 20 past midnight to five, and the bigger the possession you want, the more people want in. The contractors are wanting in, and rightly so. But inspections, ... inspections are not at the lowest end of the pecking order... but its not at the top ... and you're forced to go green [work in a green zone means traffic is not operating], but if they wont allow us in when we want in [respondent shrugs shoulders]... so we have to write a

⁵²Red zone working rarely occurs now – but it means that traffic is operating on the line that is getting worked. It is a possession *between* traffic. The comment from INT: 05 regarding the amount of time between traffic whilst completing an ultrasonic test was done in a red zone possession – organisation of this is critical. Phone calls between worker and signaller are imperative. The signaller can warn traffic of the workers; stop traffic; and tell the line worker exactly when a service is next due. A green zone possession is when there is no traffic operating anywhere on the line that is being worked on.

compliance report to show the amount of inspections we've done, which is seen by our bosses and Railtrack and they'll find out that if we're not getting proper access, inspections could fall down. So they might be forced themselves to give us access. ... We can put in an application to central planning, 13 weeks ahead; a year ahead. We now have generic inspections kicking in... at the same time, but the problem with generic possession is there are maybe too many folk wanting in at the same time... so there might be a problem of having a possession but not being able to do your work. So we don't get in, or Joe Bloggs is not getting in... so it causes problems. There's going to be a fall back somewhere along the line (Int: 07).

In describing delays that can occur during possessions at night, another worker highlighted still more problems:

A good possession will be from 12:30 midnight to 5:30 in the morning. In some areas possessions are three hours on a week night, that's a night shift green zone working. During the day, that's red zone working on the [name of line between two places], possessions are as little as 15 minutes. On the [route name] we can get an hour between trains sometimes during the day... depends on the rate of traffic at that time. ... At night, although you have a possession from 12:30 to five, the last train might be delayed, can't get on the track till 1 o'clock. Once all the passenger trains have moved through there's the [name of company] train, then there are the [name of business] trains and they can run in the middle of a possession, and that means that someone has to go to each end [of the site possession – which can be some miles apart], take the boards down, then put them back up, and that can take 30 minutes each. So there's quite a disruption. Planning possessions is quite an onerous task (Int: 03).

To conclude, we should recall how Railtrack was set-up as a non-engineering organisation (see chapter three: 3.3.3 page 100). This view has been backed up in a revealing report⁵³ which may explain why there are problems regarding communication between train companies and IMCs, and why there are problems during possessions:

⁵³The 2002 report was commissioned by the then Department of Transport, Local Government and the Regions. It was entitled "The GB Railway industry. In Its Own Words: Problems and Solutions".

Interviewees felt that Railtrack failed to focus sufficiently on its core business of maintaining its assets. Many believe the company did not see itself as an infrastructure manager. Indeed, some participants suggested that Railtrack would have performed better if “one tenth of the effort that was spent on commercial concerns was spent on engineering”. This view was broadly accepted by Railtrack (DTLR, 2002: section two).

And from the same report:

Railtrack was felt to have followed and suffered from a “hands-off” approach to infrastructure management. Interviewees felt that Railtrack was left with - and did not address - a lack of sufficient information or experience to make informed decisions on the upkeep of the network ... [additionally] Railtrack displayed an arrogance that made collaboration difficult (DTLR, 2002: section two).

These comments and my findings appear to mesh together cohesively. Nevertheless, in the later stages of my research, when the organisation of the industry changed, I was told:

The relationship with the TOCs is moving towards a better relationship... but it is still really us and them... it's all very political, they've got share holders... but it is getting there, it's moving to a formal process (Int: 29).

5.7 THE NEXT THREE CHAPTERS

In this chapter I investigated the structure of a maintenance company to see who is involved with rail and railway maintenance. In doing so we saw how teams are organised and how they interact. We were also given a glimpse into what problems exist for the individual maintenance teams – such as getting into possessions and working with procedures. In the following three chapters we take a much closer look at these problems whilst we examine respectively, the skills of the visual inspector; the ultrasonic operators; and manual rail-grinding teams, by illustrating their work comprehensively.

6 TOUCHING AND LOOKING: SKILLS OF VISUAL INSPECTION

My fingers were an intake valve through which my mental reservoir was being filled; of course, my eyes and my ears were helping in the process, but what I learned with my fingers and my eyes together seemed never to forget – Walter P. Chrysler (cited in Ferguson, 1993: 50).

6.1 THE PURPOSE AND PLANNING OF VISUAL INSPECTION

6.1.1 When to inspect and what to inspect

Because of the rail's inbuilt limitations⁵⁴ (see chapter four: 4.2 page 111) continual, timetabled monitoring of the rail's fitness-for-purpose is required. A key method in Britain is the frequent visual inspection of the track and rail by competent personnel. The working environment on the railway, however, is generally far from ideal and visual inspectors often have to make judgements on the fitness-for-purpose of a piece of rail based on their experience rather than clear evidence. In this chapter I analyse the skills of the experienced visual inspector.

Instructions on the visual inspection of the rail are contained within the Railtrack company specification "Track Inspection Requirement" (Railtrack, 2001c). This document spells out how components of the permanent way (sleepers, rail, ballast,

⁵⁴ As described in chapter four the rail as a metallic component has very little surplus strength and redundancy: excessive fatigue and excessive wear can lead quickly to rail fracture which poses an obvious risk of catastrophic derailment. Many rails tend to be subject to almost continual use also. As noted in chapter five: 5.6.2 page 149 some of the busy routes in Britain have traffic only minutes apart.

etc) and its environment (fencing, embankments, bridges, platforms, gates, etc) should be visually inspected and when and by whom:

The persons undertaking these inspections are not necessarily designated track engineers, but shall be able to demonstrate competence through relevant knowledge and experience... [and when conducting]... routine visual track inspections [they] shall identify defects which if uncorrected, could affect the safety or reliable operation of the railway before the next inspection. Particular attention must be paid to new defects and to the development of existing defects (Railtrack, 2001c: 8).

The document lists what should be inspected, such as:

Visible rail defects, including head checking and other cracks, breaks, rail head damage and significant corrosion;

Excessive side wear

Check rails for security, wear and flange way obstructions;

Broken, cracked or defective fishplates... and so on,⁵⁵ (Railtrack, 2001c: 9).

Before adding:

...Other items shall be included according to local conditions (Railtrack, 2001c: 8).

Inspection is:

Carried out on foot, supplemented by cab-riding, by the track engineer responsible for the maintenance of the track inspected (Railtrack, 2001c: 8).

The inspection of the rail is also timetabled in accordance with the annual tonnage and the maximum speed permitted on the track:

⁵⁵ The rest of the items to be checked are:, altogether from the different categories of items to be inspected, the worker must look for, in all, approximately 60 [sixty] different possibilities of defect or fault.

VISUAL INSPECTION FREQUENCY BY LINE CATEGORY

Line Category	Annual Tonnage	Maximum Speed	Inspection Frequency	Maximum interval between days
1a	70 million gross	125 m.p.h.	Twice per week	4
1	70	100 - 110 m.p.h.	Weekly	8
2	38	90 - 95 m.p.h.	Once per two weeks	17
3 & 4	15	85 m.p.h.	Once per four weeks	31
5 & 6	6	63 m.p.h. / 22 m.p.h.	Once per four weeks	31

Adapted from RT/CE/S/103, 2001: 26

Figure 6-1 Visual inspection frequencies (Railtrack, 2001c).

The Specification: “Track Inspection Requirements” (Railtrack, 2001c) was released by Railtrack in April. This was the fourth edition and its release came approximately six months after the Hatfield derailment in 2000. The Specification does not include the term RCF, however, head-checking can be found but it is followed by these words: “also known as gauge corner cracking” (Railtrack, 2001c: 34 & 35). We are reminded of the problems that concerned the definition of RCF (see chapter five: 5.5 page 142). Interchanging the terms gauge corner cracking and head checking without any reference to RCF, we can surmise, added to the confusion referred to earlier. In response to these problems, the industry released the first PWSI4 also in April 2001 (the 27th to be precise), meaning the first PWSI4 appeared just three weeks after “Track Inspection Requirements” (Railtrack, 2001c), rendering the specification out of date:

This document [PWSI4 Issue 1] takes precedence over RT/CE/S/103, [“Track Inspection Requirements”] (Railtrack, 2001e: 1).

This is an insight into how quickly the industry tried to clean up the confusion over what RCF *is* and where it occurs, indeed they immediately separated the terms gauge corner cracking and head checking (recall figure 5-3, page 144) and, of course, introduced the term RCF. But, the release of these documents came some six months after the derailment, a period of time within which track walkers were instructed to look for instances of RCF.

The outcome of hundreds of workers walking hundreds of track miles saw the amount of RCF sites increase dramatically in many regions of the network:

Prior to Hatfield there were 15 odd sites in this area, now we are sitting at 550 sites (Int: 02).

The Hatfield disaster had produced a climate of fear where people in the industry worried that an identical derailment could occur again and soon. But,

At that point, because it was a relatively new defect a lot of people walking the track didn't know what they were looking for... (Int: 02).

Emergency and temporary speed restrictions soon littered the network, but because many did not know what they were looking for, many false RCF sites were recorded.

Post Hatfield faults were wrongly classified, they were classifying taches as RCF, which they're not The ultrasonics knew then... but not everyone. Now the track patrollers are up to date – they know what gauge corner cracking is. But there was a problem with identification: at [location] there were lots of leaves, and when leaves fall on the line they can leave little lines that looks like cracking, that's what they were reporting! (Fw: 01).

This was why industry leaders issued the first PWSI4. However, in addition to defining RCF, it also gave additional instructions on when to inspect RCF sites. These instructions are based on the estimated risk of instances of RCF cracking which involves a categorisation process based on the measurement of surface cracking:

Site categorisation is based on type of RCF, surface length of the crack, length of rail affected and whether the rail is full section or planed (S&C and expansion switches).

The longest crack should be used in categorising the RCF even if this is only one crack in otherwise much shorter cracks.

Cracks shall be measured so that the tip-to-tip length of a single crack including any branching or change in direction is added together to give the total length. Care should be taken to make sure that individual cracks, which are in close proximity to each other, are not added together to give a false result.

Cracks may extend around the gauge corner and down the gauge face; any such extension, including any branching, is to be included in the tip-to-tip measurement. If a crack has developed a chevron or branched pattern, the length to be considered is the total length of visible crack as shown below in Figure 6-2.

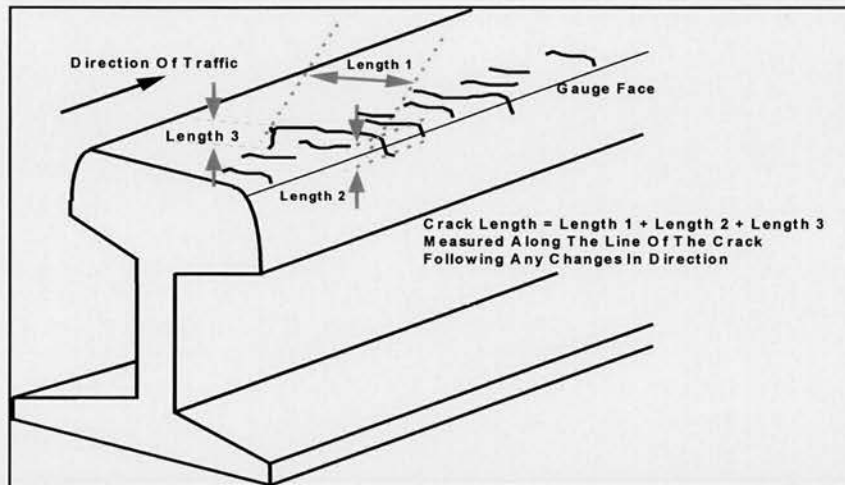


Figure 6-2 Crack measurement procedure (source: Railtrack, 2002).

Measured Surface Length of Longest Crack or Other Criteria	Category
Less than 10mm	Light
10mm to 19mm	Moderate
20mm to 29mm	Heavy
30mm and greater	Severe
Ultrasonically untestable with U3	Severe
Spalling with RCF if untestable with U3	Severe
Tongue lipping on gauge face	Severe

Figure 6-3 Crack severity categorisation (source: Railtrack, 2002).

Classifying the riskiness of instances of RCF in this way is the starting point from which all further RCF management work is guided (see figure 6-4). The activity of measuring the surface length of a crack tip-to-tip sounds simple. Surely it depends on

nothing more than to open your eyes, look, and to possess rudimentary skills with a common tape measure. What could be less complicated?

The Frequency for visual and ultrasonic inspection of RCF sites				
Line Category	Cat. 1a	Cat. 1 and 2	Cats. 3, 4 and 5	Cat. 6
Severity of RCF	Interval for Ultrasonic and Visual Inspection			
Railed RCF sites (visual only until cracking is identified)	3 Monthly	3 Monthly	6 Monthly	12 Monthly
Ground RCF sites where cracks have been removed (Visual and UT)	6 Monthly	6 Monthly	12 Monthly	24 Monthly
Light (Visual and UT)	6 Monthly	6 Monthly	12 Monthly	24 Monthly
Moderate (Visual and UT)	3 Monthly	3 Monthly	12 Monthly	24 Monthly
Heavy (Visual and UT)	2 Monthly	2 Monthly	6 Monthly	9 Monthly
Severe (Visual and UT)	1 Monthly	1 Monthly	3 Monthly	6 Monthly
Light, Moderate and Heavy RCF sites which have been ground to the specified profile under a regular grinding regime (UT only until rail has worn smooth. Once rail has worn smooth the site should be reclassified on the basis of the visible surface length of RCF)	U15 test at frequency for RCF severity prior to grinding	U15 test at frequency for RCF severity prior to grinding	U15 test at frequency for RCF severity prior to grinding	U15 test at frequency for RCF severity prior to grinding
Severe RCF sites which have been ground to the specified profile and under a regular grinding regime (UT only until rail has worn smooth. Once the rail has worn smooth the site should be reclassified on the basis of the visible surface length of RCF)	U15 test monthly	U15 test monthly	U15 test 3 monthly	U15 test 3 monthly

Source: PWSI 4 Issue 3 (1st April 2003)

Figure 6-4 Response to crack categorisation (source: Railtrack, 2002).

6.2 IT'S 25MM! HOW DID THE BASTARD NOT FIND THAT!

6.2.1 How long is a crack?

Searching for and recording surface RCF cracks that vary in length is difficult. The following collated quotes refer to problems with the procedure.

Crack measurement?... Can't get the same measurement twice. Well I found from experience that you could send me different guys to me with their measurement of the same crack and they would all be different (Int: 04).

So measurement can depend on the individual?

You can't see the full length of a crack, there are too many variables, lipping is a problem, lipping can hide defects. There was an instance where RCF experts from America and Canada came over, they found a crack and they all looked at it with the naked eye and estimated the length. The differences from each ranged from 11mm to 64mm... It was actually 13mm after checking it with a magnifying glass (Int: 01).

This means:

At the moment it is a bit of lottery trying to get an accurate crack length... it's unpredictable because at the minute its down to an individual's judgement call: I can measure a crack at 22mm, you could measure it at 25mm, and David [fictitious name] over there [colleague sitting at desk opposite] could measure it at 30mm. ... It is actually quite difficult to accurately measure the full extent of the individual crack. Now bearing in mind the guys are inspecting, say 1000s of yards of track, now for them to clearly mark the longest crack in 1500 yards of rail like this [I'm shown a picture of a rail with severe RCF] is a very, very, very difficult job (Int: 02).

Whilst another echoed:

It's all down to visual, so it's down to how we see it and interpret it differently, certainly other people's eyesight can make a difference, even if it is just 1mm (Int: 07).

Why are there differences?

The problems arise with the identification process and the inspection process for RCF... I mean, the problem lies in the daily changing of railway out there (Int: 02).

Another concurred:

When RCF first appears.... there are so many different variances, lighting conditions? Is it dry? Is it wet? My eyesight, your eyesight? Whether I was on my hands and knees and whether you were standing up... Now that is part of the problem... there are variances (Int: 03).

There are, it seems, many variables:

Visual inspection is a hit or a miss; it can depend on the type of train that passes between one inspection and the next. I might see some gauge corner cracking, a train passes, takes the skim [of the rail head surface], the next person inspecting doesn't see it. Over a period of six to nine months you can have the same rail with different findings. In that way it's unpredictable, you could walk the track, then find it, a little later, not find it (Int: 21).

And:

Weather has an effect as well, if you could imagine a crack... it can open up with the weather, and what they're finding is that in wet weather it is very hard to pick up [to see]... With heavy and severe cracking it can be easy, but with sunlight effect you can lose it (Int: 07).

Spotting cracks at night could be difficult then?

It certainly is, using visual techniques (Int: 27).

So why is it measured this way?

They decided on visuals... Visuals: everyone can do it fairly quickly, but it's not that accurate, and it causes a lot of problems that we've had... You categorise a crack length at 20mm, then a Railtrack engineer or manager walks along the track: that looks longer than 20mm... he measures it... it's 25mm! How did the bastard not find that! ... Anyone can go on their hands and knees and see that it's that bit longer, but these guys have to walk and measure the longest crack in between trains, and at night (Int: 03).

Visual inspection is a core part of RCF management, so there must be knock on effects after measurement?

Ultimately, if the crack is sized an instruction is imposed, the trains have to slow down, they're not reaching their destinations...etc. So, if the crack is categorised wrongly it tends to be expensive, (Int: 27).

Because of these problems with visual inspection, what are the general thoughts on the categorising process and technique?

You need to have something laid down, it's as good as anything else (Int: 06).

And:

I suppose there has to be a cut off point somewhere... and my eyes, your eyes... they're not the same (Int: 08).

But still, we are told:

As a technique it's the worst thing we've ever done, categorising RCF visually... there's too many variables... ultimately what we are asking the guys to do is walk the length of an RCF site with trains passing every seven minutes and measure the longest crack! Now to do that job properly he has to be on his hands and knees measuring every crack (Int: 03).

Others, however, offered a way out from problems and false classifications:

Categorising RCF by visual examination is too stringent, one millimetre more and the crack is severe instead of heavy, or heavy and not moderate. Maybe if there was a 5mm berth between categories... (Int: 04).

Or:

Oh it's got to go [the visual process]. Personally I think it's got to go, got to be done mechanically, got to be more exacting... you'll never get rid of human error. Need a better system, something digital. It's getting closer to this with the UTUs [train-based ultrasonic testing units] and the Sperry walking sticks [see next chapter, page 191]. It's not the case where you'll

get someone saying it is 5mm and someone saying its 35mm, but there needs to be a better testing system. If it's a machine picking it up, it'd be better... better for the infrastructure (Int: 07).

Given these views and opinions regarding variables, how are visual inspectors trained?

There's no training in identifying RCF, track patrollers are shown pictures of it... they cover themselves now by reporting "possible RCF"... but the majority are just briefed (Fw: 02).

Whilst a laboratory based technician said, interestingly:

If I was to go out on site, even though I've seen it in the lab, I probably wouldn't be able to put the two together the way that someone might who has been looking at it for the past five years. So it is experience, I think the guys out there, once they're shown what they're looking for, they'll see it (Int: 27b).

The last line of this quote – *once they're shown what they're looking for, they'll see it*, - is troublesome as it suggests that RCF is relatively easy to spot and recognise on-site if shown an example of RCF prior to inspection. In light of what others have said, this seems a simplification.

6.3 WHEN PICTURES ARE NOT GOOD ENOUGH

6.3.1 The necessity of experience

When I interviewed industry members some referred to the importance of experience when undertaking a visual inspection.

You need someone to know what they're looking for. It's like... you have a new guy looking "Jings! Look at the size of that!" Whereas the experienced guy will say, "I've seen worse". And that's what happens when looking at a wheel burn; a new guy will see it and think the worst, but an experienced guy will have "seen worse", you need experience and being sensible (Int: 08).

Similarly, another said:

You identify RCF by experience, only by experience. There's no training course for the identification of RCF (Int: 21).

To overcome problems with visual inspection of RCF, experience is critical.

"Knowing" precisely what to look for is vital, thus "not knowing" can have severe consequences:

Respondent: ...So there is an analytical process that goes on [when the rail inspector is] looking at the system [the permanent way].

Interviewer: And experience is a fundamental part of that?

R: Oh that's right, that's right, yes, very much so. And how do you cope with that, because nobody shadows anybody anymore. So how do you gain that experience?

I: Is this a problem: not passing the experience onwards?

R: RCF was not perceived as much of a safety risk as it is today... Following the Hatfield derailment there is a fear in the industry that could cause another Hatfield, and who would be responsible for that? Psychologically, that has an important bearing. ... Immediately after Hatfield there was an awful lot of inspection of the track in Britain and a lot of rails were taken out as a result of that inspection and a fair length of track that was taken out need not have been taken out. But, people were being... safe... guarding their own backs. And that is still going to happen today: why should I take the responsibility if it breaks? (Int: 23).

It was noted in chapter three (section 3.4 page 102) that when valuable experience left the industry it was increasingly difficult to transmit (pass on) key skills onwards, because in BR days a fundamental method of learning for the new-comer was essentially to watch how the experienced workers worked: new-comers shadowed the experienced. Today however, nobody shadows anyone anymore. What this means for visual inspection of RCF now, is significant:

Although Railtrack had known about gauge corner cracking before Hatfield, the company lacked the engineering knowledge to understand how fast cracks could propagate through a rail and even the extent of the phenomenon on the network. In the hasty privatisation process key railway skills [i.e. competent visual inspection of, and assessment of, instances of gauge corner cracking] were lost as a result of the fragmentation of British Rail into nearly a hundred companies (Wolmar, 2001: 3).

Visual inspection for RCF is not a simple activity; this argument is reinforced in the following as I show the imperative role of experience and further skills.

6.4 VISUAL INSPECTION OF RCF SITES

6.4.1 Finding out who's doing what and where: some informal arrangements

In the remaining sections of this chapter I order fieldwork notes from different times and mesh them together to give a full picture of the skills required for visual inspection.

Willie, Gordon and I meet in the car park before Mark appears, driving a van. We all get in the van and drive into a dark yard by some railway sidings of a main line. There are some pieces of rail lying around. There is some activity in a nearby Portakabin, but generally there are not as many people here as there was last night... (Fw: 02).

Last night there were lots of vans and:

Lots of people in reflective jackets moving about, there's no movement of tools, just people getting together; talking; moving on; and talking to someone else... Mark is talking to another man and looking at a book that details the routes in the area and the location of different signals. Mark is telling the man with this pad of paper which signals he is working between tonight, he seems to be double-checking everything is ok. Later I ask Mark about the point of going to the dark yard. *"When we're [working] in [this region] it's a meeting a place, and it's a place where you make sure that there's no problems with possessions, and you find out who else is working in the area, you see what's happening"* (Fw: 01).

Back to tonight:

Mark parks the van and Gordon gets out a flask and pulls down a folding table from behind Mark's seat. We have a cup of tea whilst I, Gordon and Willie chat. Mark has been using his mobile phone for most of the time since we met. He has been telling someone where he is working tonight; what time he hopes to be finished; and what he has been doing during the day. He refers to his sleeping pattern: *"three hours this morning, three hours in the evening; that was all I could get"*. Enquiring about each other's sleeping patterns is a common topic of conversation.

Mark is still on the phone. He asks the person on the other end where he and his (UT) team are working. He asks if they are going to be in that area all week. Mark offers his services for maybe Wednesday night; he has to see how things go (Fw: 02).

Already it seems to me that workers (UT operators, at least) communicate often; Mark is rarely off his phone to the other teams as conversation moves from general chat to matters about work, which is often about who is working where, or if others can help, or if there are delays that others need to know about. It seems that even though work is planned in advance, there is an informal set-up between workers that helps work to get done systematically. I asked Mark about this:

"Yeah, I suppose it is like that... well... grinders finding cracks can panic, they're grinding a crack that's got a surface length of 20mm, they grind further and it goes to 40mm, they call us and we go down and check it with the UTs. I won't put it down [log it on paper] that I've been there... it's teamwork".

We spend about 20 minutes in the dark yard. A couple of people come to the van to speak, but only about copying computer games and humorous emails. There is a real comical moment though when someone approaches the van with a massive, dusty heavy torch which is encased in black metal and has a lens that's about 12" in diameter. (Due to the hours the men work, having torches is nothing out the ordinary, but this old weighty example looks like a throwback to the early railway days for it is certainly nothing like the smaller, lighter torches now used). The cumbersome torch is attached to thick leather straps which are roped around his shoulder allowing it to hang

by his hip. Mark asks where he got it: "*I found it in a shed!*", he says incredulously. Mark mentions how it must be quite powerful, to which the man with the torch throws a handle and a shaft of light fires into the night. He aims it at one of the terraced houses away in the distance at the top of one of the hills that borders the yard. It illuminates a bedroom window and the surrounding wall. The five of us all laugh as the guy with the torch says, "*That'll wake them up*". And it sure does! Seconds after switching the torch off, we notice the bedroom light comes on as a startled looking figure appears at the window. The man with the torch laughs and turns and leaves us. Whilst laughing, Mark decides we should focus on work.

The front of the van is in the same state as last night; papers everywhere. Mark shuffles some and looks at them. "*What is it tonight?*" I ask. "*Only visuals*", there are five sites, two are on the same stretch of rail close together and the other three are also close together and again on the same stretch of rail (Fw: 02).

6.4.2 The foul four foot

It's the first time I have walked on the permanent way (the actual railway track). I am constantly watching my feet in my heavy steel toe capped leather boots. Each step seems unsteady as I make my way through the four foot (between the rails of the same line – see glossary). The ballast is loose and my footing is always thrust to an awkward, uncomfortable angle. My torch is focused on the ground in front of me. In the interests of my own personal safety, I don't look up for long; I am too intent on knowing what is beneath my feet and what obstacles are coming my way. However, I am aware that we are walking through a long valley where the thick undergrowth stretches above our heads which adds to the darkness.

I have to steady myself often. Apart from the ballast, there are broken glass bottles; crushed beer tins; I saw a golf ball; a dead cat; loose bits of metal; lumps of wood; brick; and general rubbish like polythene bags. I try to adjust my stride so I only stand on the concrete sleepers, but they're too close together for any comfort, I have to go back to walking on the uneven ballast. Every so many yards I see a dark mess with what looks like paper, I can have a guess at what I think it is, but I ask anyway. "*Shite*", says Gordon, "*I couldn't believe it when I first started on the railways*" (which I find out was about 20 months ago). Gordon was genuinely shocked when he first found

out that when the toilet on a train is flushed it goes straight on to the track. He goes on to talk about the hazards. *"See that golf ball? I wouldn't touch it, what's on it, or underneath it? Rat shit, fox piss, shite from trains?"* He also told me how workers can panic in a red zone (when trains are liable to pass) when they see a train approaching with spray emitting from one side. This means someone aboard has flushed the toilet, and the guys, despite already being over six feet away from the line try to scramble to a safer distance.

We walk on over this unforgiving terrain. I notice, when I do look up, that the three guys with me walk in steady confident strides with their heads held high, indeed Mark must as he's looking for mileage posts hidden in the overgrown hedges and bushes. He continually shines a torch from his clipboard to hedge, looking for a sign. All the tripping, stumbling and adjustment of step is done by me. We eventually find our mileage post from which Mark strides out counting his steps; he's finding the yardage. He counts about 70 strides / yards, we follow behind him. He stops and looks; he can't find what he was hoping to see: a reference number on a sleeper and mark on the rail. (The fault we are looking for is gauge corner cracking and it's due for its 12 monthly visual inspection, the line is category four and line speed is 85mph). He discusses the absence of any paint mark with Gordon and Willie, where-upon Gordon remarks that may be it was last marked out by a guy with a longer stride. Mark is a small guy and of course this will have a bearing on where the location is, if it is measured by strides. We walk on a little further staring at the web of the continuous rail until we see some faded paint; Mark has a close look and claims this is it (Fw: 01).

6.4.3 Still feeling the effects of Hatfield

We crouch down low and have a look at the rail. The fault is apparently on a thermite weld⁵⁶. With four powerful torches shining on the rail at this point, and with my eye just several inches away from it, I could see nothing that resembled gauge corner

⁵⁶ This is the type of weld where lengths of rail have been welded together, giving the effect that the rail is long and continuous. These types of weld have replaced the older way of connecting rail with "fishplates", thus the name of this rail is now referred to as CWR – continuously welded rail.

cracking, or what resembled gauge corner cracking in a photo from the booklets issued by Railtrack that I had looked at in preparation for my fieldwork. Almost immediately I am convinced that there is no cracking here. Yet Mark continues to look. Surely it is obvious that there is no cracking here? Some seconds after I convinced myself that there was no cracking, Mark agrees: "*Nothing, no cracking here*".

I am aware of the time difference between us. Even though we came to the same conclusion, the length of time Mark took to make up his mind was longer than me. This is my first inclination that perhaps looking for a crack is, indeed, not that simple. If there was a crack there, would I have missed it? The men I spoke to in my interviews before my fieldwork were perhaps on to something!

So no crack; I presume this is good news, and say so to Mark who replies: "*I knew that there would be nothing here.*" I am taking aback by this comment as I feel that the last hour or so has therefore been a complete waste of time, so I ask him what he means. He was certain that he would find nothing. He tells me that cracking at thermite welds is "*peculiar to this area, but not on this one stretch of line*". (He's been in this area for 12 years). He explains what he means:

During the aftermath of Hatfield everyone on the track had a duty to keep their eye on the rail, thus many instances of gauge corner cracking were reported. But there was a lot of panicking, and false reports were submitted, people didn't know what they were looking for and were claiming they had seen gauge corner cracking in different areas. Now as soon as gauge corner cracking is reported it is fed into a database. And (as I knew already after speaking to managers) Mark told me that "*RCF never becomes historical, it is always alive*". So once gauge corner cracking is reported and regardless of whether "*it is the real thing or not, it remains in the [IMC's] database*" (Fw: 01).

I had just experienced an effect of the Hatfield derailment: someone who didn't know what they were looking for had walked this line, spotted something, thought it was RCF and reported it. It was a false site. The outcome of panicking, or not knowing what was to be looked for during those days, was felt tonight, some three years later.

But what occurs when there *is* a crack? The following sets of notes delve further into the activity of *looking*: we see how tacit skills combine sound individual judgement and interpretation to underpin RCF management decision-making. Ideas of individual judgement, interpretation, tacit knowledge and risk-management are all latent in the following.

6.5 ANALYTICAL PROCESSES (1-3)

6.5.1 Looking for RCF in the middle of the night

After traversing some filthy obstacles on the permanent way we arrive at the site. Mark has counted out the yards again and we have found the paint on the rail. It's a thermite weld again.

The three of us peer down at it. On bended knee we focus the torches very closely. I can't see anything, but conscious of the fact I don't think I really know what I am looking for I ask Mark what he sees. "*Nothing*", he says eventually and hesitantly, but he seems to be unhappy with something as he constantly wipes the rail with his thumb and peers at it from different angles. Then with authority he says there is, indeed, nothing there. We walk on to the next thermite weld, this is the second site.

At the second site we go through the same procedure. Three guys bent double eyeing a piece of metal from close quarters shining torches on the suspect. Mark uses the sole of his boot to rub the surface then peers down again. He seems a little more attentive to the matter tonight, unlike last night where he decided in seconds that there was no cracking. Once more I am keen to try and see something; there are specks on the rail on the running surface:

"Is that anything to be concerned about?"

"No, that's ok, that's nothing", says Mark.

Looking closely but not touching with his hands or fingers he rises up from the rail and says "*nothing*" is there, but then turns and walks toward the first site that we just had a close look at. We get to the first site again, and from a standing position Mark shines his torch on it, and then with the beam of his light he traces the route of the rail in the direction from which we first entered the railway (Fw: 02).

6.5.2 An analytical process (1)

He walks after the beam on the rail. I follow him. Lifting his line of vision from the rail to speak to me now and then and to watch where he is going, Mark tells me that, though he is not scheduled to, and though he doesn't have to, he is going to check the weld further down the rail, his reason being that there are problems with thermite welds [at this location] – "*it's curious*", he says.

We get to the weld and Mark immediately lowers himself to get closer the rail, he only bends at his waist. He is in the 4-foot (between the rails) and I am in the 6-foot (between the two sets of lines – see glossary) and we are both looking at the right hand rail. I am also trying to get a close look at the rail: I am bent at the knees and closer to the rail than Mark. "*There is something here*", Mark mentions after a moment. I lean further over and can't see anything; I ask him where the problem is. He points at it, I still can't see anything. He says it's on the gauge corner (i.e., the corner that is partially out side my line of vision) and that I should stand in the 4-foot. I go to the better angle, go down on my knees and without being prompted to its precise location I try to look for the fault on the rail. I still can't see anything; my eyes are flitting over the surface of the rail too quick I think. "*You see, there it is*", Mark says, and he points directly to a small area of the rail.

I focus my eyes, squinting at the rail, I examine the rail closely and eventually I see a crack *emerge*.

It is as wide as a single strand of hair, and to me it seems to be working its way from the corner and partially down the gauge face. It's running at an angle to the ground, like a jagged, fractured crack in a pane of glass. The crack, from the gauge corner, slides down from the right to the left and onto the gauge face. I try to see where it

starts and finishes. Where I think it ends at either point is different from Mark's perspective. He has a small plastic measuring rule and places it against the rail just where the crack is. He manoeuvres the rule around the crack, taking into account its growth pattern in one process, and says: "*it is 20mm!*".

He seemed to finish measuring it at a point where I could see no crack. So I ask him:

"Where does the crack start and end?"

He points to either end, I can barely see any problem, and as if Mark is aware of my uncertainty he says,

"See the slight shadowing, that's its ends".

Shadowing! There are numerous shadows on the rail because of our unsteady hand held torches and distant lamp-posts, so I can't really see anything; I can only take his word for it, perhaps if I had 12 years experience of looking at rails (as Mark has) I might notice something! Still, I remember hearing railway workers speak about the fish scales-like feeling of the cracking, so I run my finger along it firstly in the direction of traffic. I can feel nothing out of the ordinary, just a smooth piece of rail, but then I drag my finger back along it, against the flow of traffic so to speak. This time I can certainly feel something; something akin to a serrated edge, any quicker and I might have nicked a bit of skin. But the thing is, I could feel something beyond my sight, I could feel it, but couldn't see it. And where I couldn't see it but could feel it was where Mark had continued to measure – that area in the shadows. I then remember about the hazards and the filth that gets dropped on the track. I should wash my hands as soon as possible.

I am genuinely impressed at Mark spotting that crack, and though I have asked him before, I ask if he can tell me precisely what is involved in looking for something that small, in this light. He tells me things along a long these lines: "*You get to know the area, you know the problems that can occur, you know what to look for, the shadows,*

the shading". He also refers to luck, despite experience, luck still has a role. "*You can't walk with your head bowed all the time, you'd break your neck; you look down every couple of yards and hope you find something*" (Fw: 02).

When speaking to me to explain what was involved, Mark looked uncomfortable with the terms he was using. He could not tell me precisely how you go about searching for a crack. It became clear to me that there was no concrete formula to "looking". There was not a skill to "seeing" that could be "said". Indeed there was something implicit and tacit; there was something un-stated about the way he knew to go on and look at the third "unscheduled site" – he just thought he should do it, and the exercise was fruitful.

Mark, as his set workload instructed for that line, checked two sites, but then he checked a third unscheduled site: Why? There was an analytical process underpinned by experience that shaped his decision. What he had done, or rather why he had done it was built upon a degree of tacit knowledge that suggested he should look elsewhere. The product was an exercise in analytical risk-management: an exercise which was best described by an industry scientist:

In the application of the rules, people can treat as black and white... but because the science is not fully understood you need the human interpretation, the plasticity of the human brain, to be able to look a various aspects and come to a conclusion: "that is what is needed." The efficiency of one inspector to another... I think the difference is that: somebody who wants to satisfy the rules, "it is not my jobs-worth, I will simply measure it black and white and report it full stop and the responsibility is finished". Whereas the other guy; "I can see a crack here this size but I can also see that the sleepers are skewed... or the rail pad is missing therefore I can understand what is happening here and I will come and inspect it in three weeks time. And so on". So there is an analytical process that goes on looking at the system (Int: 23).

Another reason why railway maintenance workers have to adopt an "analytical process" is because of the actual nature of the permanent way. The "permanent way" is a misnomer; some refer to "voiding" to describe the movement of the track as trains

pass over it. Each part of the track moves in its “own way”- each section of track can develop a memory, meaning each section of track can develop its own idiosyncratic problems peculiar to that location. The consequences for inspection have been mentioned:

There’s a good chance that, historically, it [RCF] will come back in whatever timescale.... You can do any work to a track but it will go back to its existing memory that it had, there are so many moving parts that it will go back. There’s no point in saying – I’ve identified a realignment problem there, realigned it and walked away, - you have to re-visit maybe 4 – 5 times because it will go back to the way it was (Int: 02)⁵⁷.

Why Mark assessed an *unscheduled site* was an example of the analytical process ticking away: he accounted for the idiosyncratic nature of the permanent way. In the next section we see further examples of the analytical process at work; additionally the notes come from research that was completed during the day: we can also assess the idea that RCF inspection would thus be easier.



Figure 6-5 Example of how gauge corner cracking is labelled with paint on web and sleeper (author’s photograph).

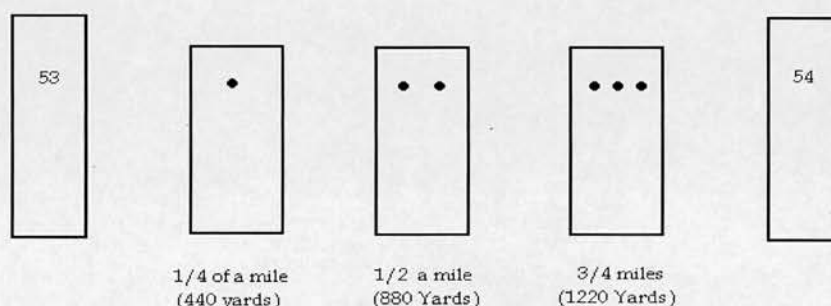
⁵⁷ On the same point, a retired railway man who spoke to Jack (2001: 59), told him that a rail, if it has been transposed (turned around so that its gauge corner is now on the field side) for instance: would want to assume its previous form: “to go back, as he said, to where they lived before.”

6.5.3 Looking for RCF during the day: Safety, trust, and... where are we?

We find a dirt track that leads up to a big metal gate with a Railtrack sign on it bearing a warning to trespassers. One of the team (there are five of us) gets out of the van, unlocks the gate, and we drive on 20 yards to the track side. We all get out of the van. My PTS card is checked and I sign my name by it. I am told: where I am; who the first-aider is; what line we are walking on / inspecting; and that the line is not blocked; that there is traffic operating on both lines and capable of speeds up to 125mph (red zone working). The first thing we do is look for a mileage post to get our location, but this is proving difficult. We look down the line to a bridge which corresponds with an "over bridge" in the map; we see another bridge that again corresponds with the map, but it is a mileage post that we definitely need to get the yardage. This tells whether we are a quarter (440 yards), a half, or three quarters away from the next or last mileage post – and the precise yardage is what we need prior to inspecting the rail. Each quarter is marked by a post with one, two, or three dots or strokes on it respectively.

Mileage post: how to get to the fault

NOT TO SCALE



If we were on the permanent way and were looking to retest a site that was at location: 53.889, we would look for the mileage post: 53. When we found "53", we would continue to walk until we pass a post with one dot, as above (or vertical dash), and on to the next with two dots. The second post with two dots means we are at "53 and a half miles", or 53.880. Then, at this point, we would walk approximately nine full strides and look for a paint mark on the web of the rail or a spray painted reference number on the nearest sleeper.

Figure 6-6 Reading mileage posts (author's sketch and example).

We ascertain the yardage from which we should start our inspection. For the inspection we have to turn on our heels and start walking the way we came (towards the

oncoming direction of traffic) but this time one of the men has a mile- o-metre, (on the cess rail – see glossary) marking the distance we travel and this time, instead of walking in the cess, myself and Alec are in the 4-foot: between the rails and in the centre of a line where traffic is live and travelling fast towards us.

Despite the fact that one of the men remains quite some distance ahead of us and able to see the stretch of line coming into the curve we are on, I am a little apprehensive as I realise that this job requires me to look at the rail more or less 100 percent of the time. This gives me little chance to look up, thus I need to place my full trust in the men looking out for my safety. The man – the look out – who is some distance ahead of us is armed with a horn and a whistle (and a flag) and he alerts us of approaching traffic. When he does, we have to immediately stop what we are doing and move to a position of safety – approximately 4 - 6ft away in the cess. The site warden and the COSS make sure that we do not “wander” onto the other track. They were also adamant that we should not take notes within the 4-foot. In these conditions we walk along the uneven ballast peering at the rail to my right hand side (Fw: 07).

6.5.4 How a rail should be

This rail to start with, John points out to me, is the way a rail should be. There were no grinding marks on it and the running band round the curve was steady and just off centre towards the gauge corner. And above all else the rail was shiny, indeed it was gleaming and that was how it looked for nearly 440 yards. The permanent way here is neat with no debris. John and I walk promptly along this stretch of rail until he stops abruptly. We stood silently for a moment. John looked intently at the rail, so did I: I couldn't see a problem until John lowered to the rail and pointed to an area of the head. Then I saw some cracking. It looked to be quite long cracks over a length of rail covering a few inches then nothing. I couldn't see it from a standing position, but John did and labelled it “moderate”. From then I could start to see where lengths of affected rail started and stopped. Small cracks, perhaps only two-to-three millimetres long and about an 20 – 50mm apart started to appear, gradually they would grow longer as the distance was covered by walking, then like a symmetrical pattern they faded away in the way they materialised. Again it was like this for about two hundred yards, ranging from extremely light (see categorisation table, page 157) areas to patches of moderate cracking – John never labelled any cracking here as severe (Fw: 07).

6.5.5 An analytical process (2)

We find a rail with numerous taches ovals and wheel burns. John doesn't like the look of it. Though no individual crack length is long enough to be classified severe, according to the PWSI4 categorisation table, John simply doesn't like the way the rail looks. He stands over it, eyeing it with a furrowed browed; "*it just doesn't look good*", he labels it as "severe". It's the first time I have seen a rail like this and I never needed any prompting to see the faults, they stood out as dark patches like bruises on or just under the surface of the rail. (Fw: 07).

6.5.6 An analytical process (3)

We are at an S&C which was ground last week. This is a last minute inspection that John has been asked to undertake.

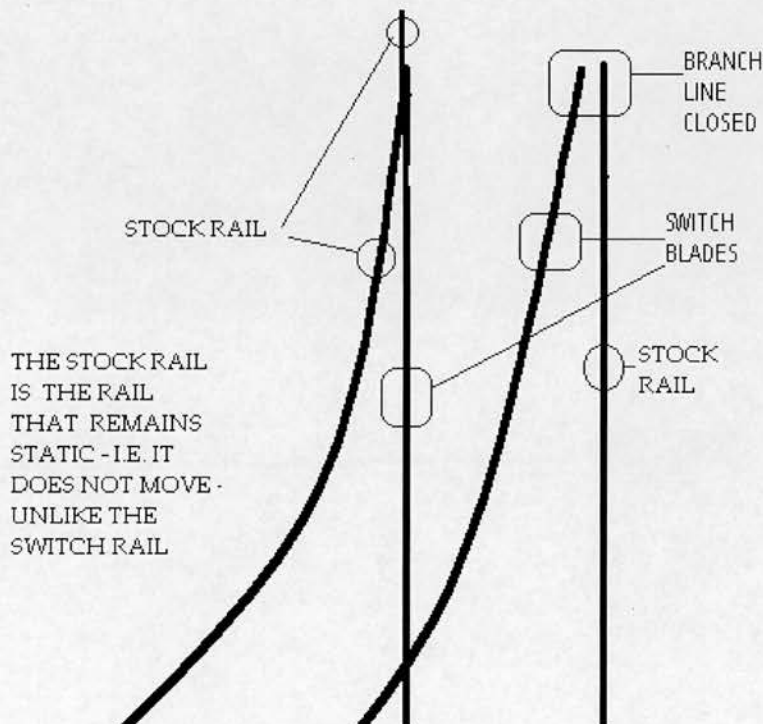


Figure 6-7 Definition of stock rail and switch blade (author's sketch).

Apparently, when they were grinding, a 40mm crack was found and could not be ground out any further and they want John to assess it.

He runs a finger over the fault, then wets his thumb and again feels the surface. He looks at it from different directions before we move to let a train pass. Instead of going

straight back to the rail once the train has gone, and even when the COSS says it is safe to do so, John remains where he is, looking at the S&C as a whole, eyeing it up and down from a distance, then eventually we go back to it.

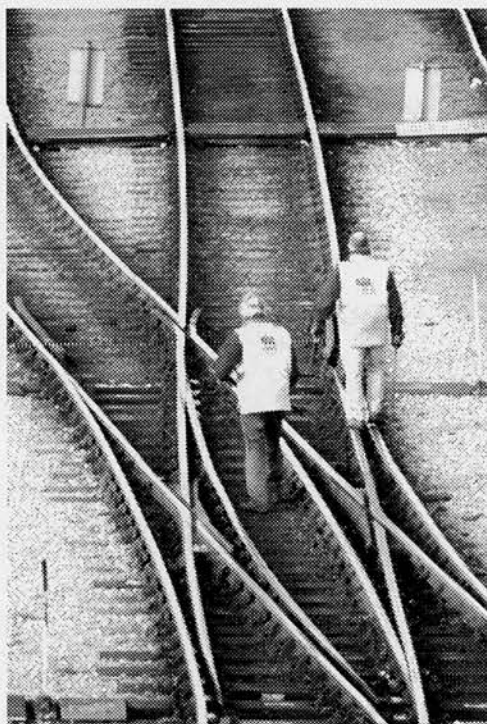


Figure 6-8 Two visual inspectors at a switch and crossing (internet source: Alvey and Towers photography).

The moment of just standing and looking at the S&C was for an overall assessment of it. John says he is unhappy with the entire S&C. Firstly he tells me that the crack, in his opinion, is only a surface crack [that is, it doesn't descend into the main internal body of the rail head], then he highlights the running band which the crack is in. It is on the stock rail and it is not steady: it wavers from side to side – unlike the opposite rail that runs on a steady straight line. He has a look at a sleeper and the chair and the pad; bolts are missing and the wooden sleeper is split. This is not good and “*could be causing all sorts of problems*”.

He then pushes a stretcher bar with his foot, it moves – it is not fitted tight and solid, John shakes his head. We look at the switch blade, John points out that it is fractionally too high – it is higher than the stock rail that it should be flush with. Altogether, the

entire S&C is in poor quality and needs a lot of attention. All these factors could have caused that 40mm surface crack (Fw: 07).



Figure 6-9 Example of head-checking on a stock rail of a switch and crossing (author's photograph).

6.5.7 Looking for clues, knowing the symptoms of problems, and silent trains

When instances of RCF were found, John looked for the rail's information, like where it was produced (i.e., Workington or Glendarrock); how old it is, (I saw rail that had been

in place since 1973 and rail as new as 2002). This information is welded onto the web of the rail. It can be hard to read on occasions if the ballast is too high. Also, when the rail starts to rust the writing on the web can be defaced. Indeed, finding the web information hard to read is a symptom of too much ballast, John told me. Nevertheless, he wanted this information for his papers as he may spot trends (Fw: 08).

We have come across a site of gauge corner cracking. John and I are in the 4-foot crouched low and peering at the rail. He tells me it is light and runs his thumb along the surface of the rail; I do the same and can feel smoothness with the flow of traffic but a series of very slight serrated edges the opposite way. John is about to tell me something when I hear a piercing whistle; a yell of "*train*" and the COSS telling me to get in the cess. I move quickly, conscious of my footing in my heavy steel toe-capped boots on the uneven ballast. The second I am in the cess I look at the curve where the rail runs out of sight just as a train comes charging round the corner on the line I was standing in the centre of a moment ago. One moment it is at the corner, the next, numerous carriages blur into one as it rushes and thunders by hammering the ground below my feet; and then the magnetic-like drag of wind that follows its passing tries to pull me along at its tail end; and then it's gone; round the curve: out of sight. Before going back on the track we wait for the look-out to wave a flag signalling safety. "*Did you see the slight voiding?*" John asks me. I don't know what he means so I ask him to explain the term. Voiding is when the sleepers move during the passage of traffic. During the terrific din of the train and as I tried to catch my breath, John had calmly analysed the behaviour of the sleepers⁵⁸ (Fw: 07).

Despite the noise of the train as it passes, traffic on lines can *become* surprisingly quiet to workers when they are on the permanent way and working. When I walked the permanent way during visual inspection, I did so with my head bowed to one side,

⁵⁸ Most people will have experienced a high-speed train pass them when standing on a station platform. On the permanent way however, it is a vastly different experience. Remember on a platform, you are able to step directly into a carriage – on the permanent way you are not: the floor of a carriage is roughly shoulder height to one standing on the ground. As a train passes then, it is not just the speed that is awesome but the size of the locomotive is also immense.

keenly inspecting the rail. Periodically the inspection stopped as a train hurtled by. After some time I realised I was totally relying on the look-out and COSS for my safety. I had got engrossed in looking for cracking, and instead of looking up every so often for traffic, I had begun to look solely at the track⁵⁹. I found myself at times shocked to hear the COSS tell me a train was approaching and only then hear the service approaching quite audibly. Before my fieldwork I read how some accidents have been caused by trackmen being so immersed in their work that they simply never heard oncoming traffic – the idea that you could not hear a train hurtling towards you, I thought, was ludicrous, until I experienced it⁶⁰.

After informing me about “voiding”, John and I go back into the 4-foot to look at the gauge corner cracking again. It can be difficult to tell the difference between light gauge corner cracking and grinding marks left by the 64-stone train-based grinding unit [see glossary], John says. There are differences between the two when the gauge corner cracking is more severe, but when it is light it can resemble grinding marks; if you’re unsure you should record it as light gauge corner cracking, between 0 and 10mm. We both run a finger along the surface and, in a peculiar way I am not sure what I can feel, *is* there a slight serrated edge there - I ask myself. I’m unsure, so is John. The majority of this rail at this curve has been ground. So I run my finger along what John tells me is definitely grinding marks just short of the cess edge of the rail and again over the suspected marks on the surface towards the gauge corner. Again, I’m unsure if there is a difference, the grinding marks feel quite smooth either way, but so too does this possible gauge corner cracking (Fw: 07).

On two occasions when John was a little unsure he took out a tissue, wetted it and wiped the rail then tried to feel for cracking to determine if there was any. On another occasion, he stroked the rail prior to leaving the track for a train. Then he went back and felt for the cracking, but then said “*I thought I could feel it, but no*” (Fw: 09).

⁵⁹ I should not have done this, and afterwards I recalled my training for my PTS. It is ultimately me that is responsible for my safety, and that I should always look up every few seconds to look for traffic.

⁶⁰ Bridget Hutter’s text (2001) on railway industry risk management refers to this type of accident: here she quotes a Railway Inspectorate Report: “A track patrolman was struck by a train from behind as he was walking alongside a bi-directional line. The locomotive’s warning horn had been sounded as the train approached and the patrolman had apparently acknowledged the warning ... he appears to have been so preoccupied with his duties that he failed to assimilate the warning from the train” (Hutter, 2001: 60).

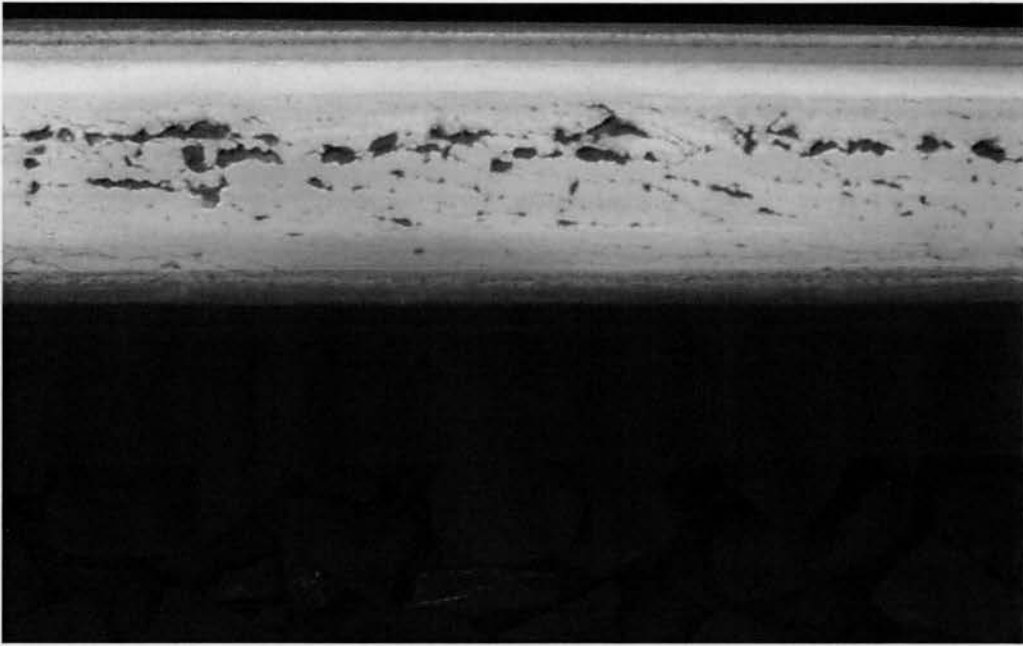


Figure 6-10 Close-up of heavy head-checking (author's photograph).



Figure 6-11 It is barely perceptible, but there is light RCF upon the rail's gauge corner (author's photograph).

6.5.8 The randomness of RCF

Another site is found. John believes that it is severe. I run my finger over it and can certainly feel serrated edges – compared to the grinding marks it is very rough. The cracking is not isolated to one area like a cluster within an inch or two as at other sites;

it is spread out over a few inches. Within this area the cracking is packed close together.

I notice how John continually refers to it as gauge corner cracking: I ask him about the term RCF. *"It's all the same; it's all faults that need attention"*. RCF came in *"as a term to cover them all"*, he says. He is also convinced that it is a new problem... he had never experience it or had heard of it until the last ten years. I ask him if he would describe it as a recent phenomenon as others have - *"Oh yes, that's quite correct"*, he says before adding that wheels on the trains have a critical affect. Beforehand, there were a variety of wheel profiles, each in its own way ground the rail in different areas, thus gauge corner cracking never had a chance to develop as it would wear first. He goes on to tell me that gauge corner cracking predominantly affects the curves on the network, it's the high rail that gets affected worse (see "cant", in glossary)... and S&Cs. You can get it on straight lengths but that's rare, very rare (Fw: 07).

We finish a quarter of a mile and start the next, this time I take a note of the findings for the entire 440 yards. The severity of gauge corner cracking is judged by John.

148 miles + 00 (the starting point).

+05 yards. Small cluster over 6 inches. Very light.

+16yds. Cluster over 3 inches. V. light.

+26yds. One individual crack. V. light.

+34yds. One individual crack. V. light.

+46 – 60yds. Continuous cracking. V. light.

+148 – 151yds. Continuous cracking. V. light.

+186 – 201yds. " " " "

+207 – 230yds. " " " "

+234 - 243yds. " " " "

+250 – 261yds " " " "

+296 – 317yds. Continuous cracking. Light to moderate.

+324yds. 3 cracks. V. light.

+337yds. Cluster of cracks over an inch. V. light.

+379yds. Cluster of cracks over an inch. V. light.

+404 – 421. Continuous cracking. V. light.

+422yds. Thermite weld, several cracks within 2 inches of weld – moderate to

heavy.

+423 – 440yds (quarter mile post). Continuous cracking. V.light (Fw: 09).



Figure 6-12 Example of an isolated single crack and its label on the web (author's photograph).

6.5.9 Testing times

After some days of visual inspection I thought I might test my ability to spot RCF. I wanted to see if my brief “training” would pay off so soon. So one morning we set off: the “visual inspector” with a handful of hours experience led the semi-retired railway man with nearly four decades of permanent way experience.

About 200yards in “we” find the first occurrence of gauge corner cracking. Or rather, John finds it. I had walked right past it, it wasn't until John stopped and asked for the yardage that I realised I totally missed it. He didn't even run his finger over the surface to know there was some cracking. He didn't even lower himself to the rail for a better look. It was nil to light [the crack length was less than 10mm long and classified according to PWSI4 categorisation], there were two cracks close together which I totally overlooked. Even when I turned back to see where I had missed it, I still needed a moment to find it. After this, however, I found that it was easier to see forthcoming sites and cracking. It was as if I had to train my eye by focusing on a rail that had RCF:

it was like I needed practice by “looking at a site” before moving onwards to look for new sites (Fw: 09).



Figure 6-13 Example of severe gauge corner cracking (author's photograph)

6.6 SOME THOUGHTS ON VISUAL INSPECTION

Experience, judgement and tacit knowledge (specifically when interpreting shadowing on the rail's surface and the feel of cracking) are critical. These

factors shape decision-making, but I was also aware of problems with this type of work, which I now discuss.

6.6.1 Problems: shadows, measurements, PWSI4 and opinions

I notice that John labelled instances of RCF as light, moderate, heavy or severe (that is according with PWSI4 terminology] but without a measuring device. I ask him about this and he dismissed the whole idea of measuring the crack with a tool. Placing a measuring tape over the crack and trying to shape it to the crack, taking into account all the turns and twists is not needed: *"You can tell just by looking at it what it is"*. And indeed that is what he has been doing. He had already told me that, when the cracking is close together it is likely to be near heavy or severe. When the cracking is further apart it tends to be not too bad. I also ask him about the PWSI4s and the role this paper plays in actual working procedures. *"If we followed them to the letter we would have to shut the network down, as simple as that"*.

John then gave me an example of an actual situation ...*"they were going by the letter in [location] they nearly had to close it down... then at a meeting"*[John at this point names two senior Railtrack engineers] *"got up and told us to treat the document [PWSI4s] sensibly... but you break the rules, your arse is out the window"*. So I ask him about the role of experience then, it must be important... *"you know what is bad and what needs attention, you can tell"*(Fw: 07).

7 ULTRASONIC TESTING ON THE BRITISH RAILWAY NETWORK

The tacit knowledge and skills of workers may not have been the determining factors in Britain's leading role in the Industrial Revolution, but they were essential components of it. Today, similarly, the knowledge and skills of workers – sensual nonverbal and subtle acts of judgements – are crucial to successful industrial production. Yet the engineering profession makes little effort to give credit to skilled and knowledgeable workers or to learn from them (Ferguson, 1993: 59).

7.1 IN THEORY: PRINCIPLES AND TECHNICALITIES OF ULTRASONIC TESTING

7.1.1 Hidden problems at Hither Green

It is not sufficient to only inspect the rail visually, the internal make-up of the rail also needs to be scrutinised using non-destructive testing (NDT) equipment. To do this, trained railway personnel use ultrasonic testing (UT) equipment. To appreciate fully and understand this type of testing, a short section has to be dedicated to explaining what ultrasonic testing is, how it works, and why it is used in the railway industry.

Pulse-echo ultrasonic inspection has now been used on Britain's railway network for over 30 years. Its implementation came after a serious derailment in November 1967 when a train left the permanent way at Hither Green, South London: 49 people were killed, 78 injured. The inspection of the internal quality of the rail at the time was by a system called Audigage, and of this system an industry worker told me:

Prior to Hither Green, rail inspection involved rail tappers. Men would literally walk the line, tapping the edge of the rail [and would use the tapping staff held against the rail and ear] to listen for a particular sound [pattern]. Depending on the sound it suggested a fault (Int: 27).

“Audigage”, however was thought unreliable, not systematic and relied excessively on individual judgement, the tester at the derailment at Hither Green was found to be tone deaf! (Brentnall, 1998: 24). Thoughts on Audigage’s inefficiencies found their roots in the investigation of the Hither Green disaster. It was:

Found that defects relating to the rail ends⁶¹ were increasing dramatically at the time and resulting in numerous rail failures. The defects consisted mainly of fishplate bolt hole star cracks on jointed track, weld failures, and the kidney shaped defect found in the rail head, now known as the Tâche Ovale. The investigation committee recommended that a research initiative should be undertaken to investigate alternative rail-testing methods and, from this initiative pulse-echo ultrasonics emerged as the technique to replace Audigage (Brentnall, 1998: 24).

7.1.2 The pulse-echo method

At a railway industry conference, the principles of ultrasonic testing were described as such:

Ultrasonic testing is a non-destructive inspection technique to assess the integrity of a solid object that is based on the principle of ultrasound reflection, also known as the pulse-echo method. A pulsing beam of electro-acoustic energy with a frequency beyond the normal hearing range travels from a crystal housed in a probe head through the material of the component under examination. For railways, the probe is placed on the rail and the ultrasound is transmitted into it via a coupling fluid, usually water. In an intact rail, the ultrasound beam travels through the rail to its maximum depth and is then reflected back from the so-called ‘free face’ to its origin at the probe. Here the mechanical vibrations are re-converted into electrical signals by the probe and are displayed on a cathode ray oscilloscope or computer monitor screen. The waveforms shown on the display are then analysed and assessed by the ultrasonic operative. When the maximum depth of the material is known, the technician will be looking for an uninterrupted signal (the signal is commonly referred to as a signature) from the boundary at the rail depth. Any discontinuity in the wave

⁶¹ The Hither Green derailment was due to a fault at a rail end, known in the industry as bolt hole star cracks. A definition of this fault and how testers test for these faults is given later.

from the specimen's depth will suggest that there is an internal flaw (Wilson et al, 2003: Conference paper)⁶².

Applying UT to the railway industry has advantages:

Another very important territory of ultrasonic testing is the finding of dangerous incipient defects in components in service, e.g., fatigue cracks and effects of corrosion. One cannot imagine, for example, efficient maintenance of a railway system without routine ultrasonic checking of axles, rails and other highly stressed components (Sziland, 1982: 45).

7.1.3 Considerations for the operator

Correct operation of the UT equipment and interpretation of its output substantially relies on the competence of the technician carrying out the test. In the following, experts refer to problems for ultrasonic operators:

In principle, information [on a cathode ray oscilloscope or computer monitor screen] suffices to locate potential defects. In practice, the traces are lively and require great attention for interpretation ... the problem is now one of information technology to assure the recognition of potential defects among the mass of tested data that will flow through the system. ... [In response to this] recent developments have sought to assist the operator by recognising patterns typical of rail ends, bolt holes, etc. The objective is to present to the operator only those patterns, which cannot be explained by typical features. This prevents the operator from being flooded with information that he must mentally process. ...

[However] current testing systems continue to be operator sensitive. The ideal operator can maintain mental vigilance over extended periods of time, using his training and experience to identify suspicious indications. ... Such operators exist but there are an equal number of excessively conservative operators who frequently stop and may mark a rail for unnecessary

⁶² In describing the principles of ultrasonic inspection, the authors relied extensively on the following documents: 'Serco 2002a: Personnel certification in NDT – ultrasonic testing of rail level 1 part 1a: general ultrasonic theory'. And 'IHHA, 2001: Guidelines to Best Practice for Heavy Haul Railway Operators: wheel and rail interface issues'.

removal where they do not recognise the pattern of indications. On the other hand, some operators are product-orientated, or are perhaps too quick to attribute unusual indications to a rail surface condition. Operator performance should be reviewed regularly (IHHA, 2001: 5-30)⁶³.

7.1.4 Technological strides and some limitations

Manual UT of the rail since the Hither Green investigation has been a regular feature of inspection. For manual inspection, the operator places a small probe on the surface of the rail, depending on where he or she wants to UT. Depending on the type of test to be completed the relevant probe has to be chosen. Different probes can emit ultrasound at different angles into the rail: different angles are used for different defects. For instance, a zero degree probe emits a sound wave directly down the rail, see figure 7-1.

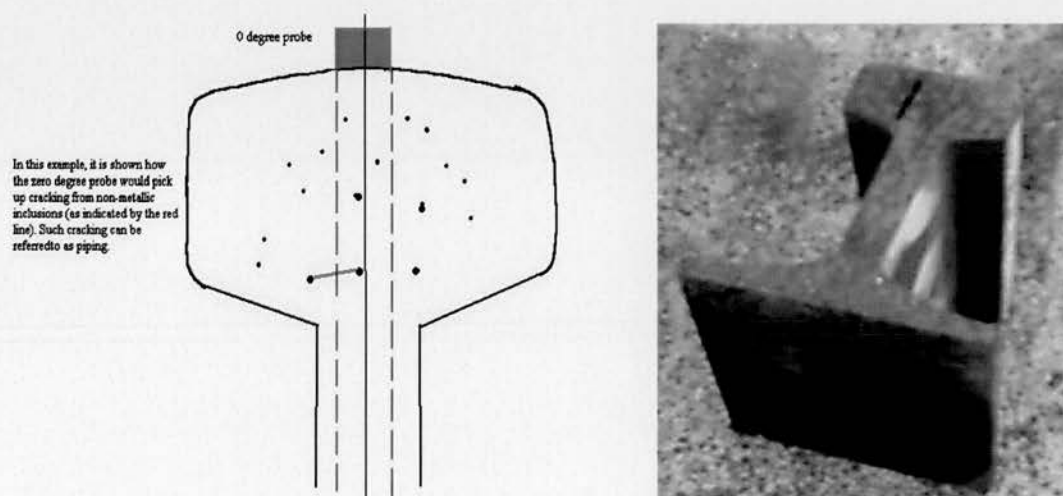


Figure 7-1 Zero degree probe and a problem it can find (author's sketch and photograph).

⁶³ Due to the demands that are placed upon the UT operator other non-destructive techniques have been sought for, but: "Many technical organisations have been spending substantial amounts of money searching for an alternative method to ultrasonics for testing rails and rail vehicle axles. Millions of pounds have been spent but no alternative method has yet emerged" (Brentnall, 2002: 29).

Other probes, such as 38, 40, and 70 degree probes emit the ultrasound wave into the rail ahead of the probe's position (see figure 7-2)

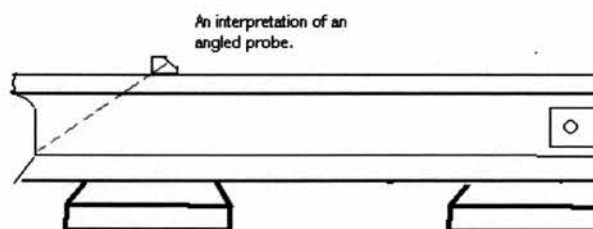


Figure 7-2 Ultrasound wave at 40 degree angle (author's sketch).

This next diagram (7-3) is a close up of the probes, and the picture shows a UT operator testing the rail with a hand held probe:

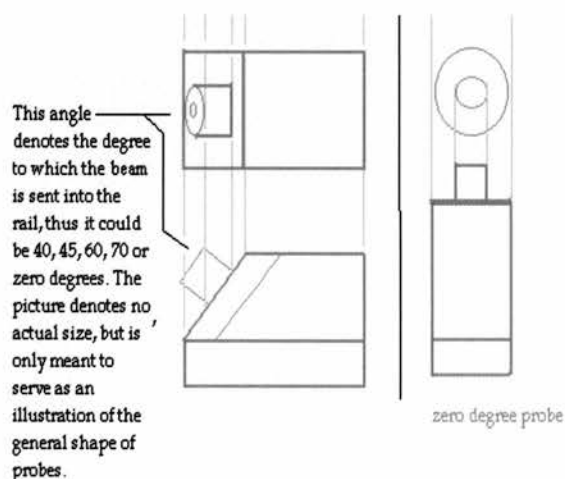


Figure 7-3 Sketch of probe and on-site operation (author's sketch; photograph, internet source: www.alveyandtowers.com).

In recent years there has also been a significant development in the use of the so-called *Walking Stick*. The walking stick is based on the concept of sliding a probe along the surface of the rail. The first type of walking stick had two probes: one probe (0°) injected ultrasound waves into the rail, and another transmitted sound into the rail at a 70° angle ahead of the walking stick. The next walking stick development utilised another 70° probe that entered the rail in a direction opposite to that of the first angled probe. This walking stick was known as a bi-directional stick⁶⁴ – the 070 RAIL TESTING SYSTEM⁶⁵ – known as the U3 because of the three sensors present. These sticks, however, did not cover the full railhead section. Technicians and operators would therefore have to rotate the stick to an angle to test the gauge corner and the field side corner. Indeed two respondents told me:

The single direction walking sticks came out in the... '60s I think... the bi-directional ones came out in the 80s... you have to wind the probe to either side to check the gauge corner of the field side (Int: 25).

U3 is only really effective for transverse defects so gauge corner cracking is only really picked up visually. But what you do is you move the probes to either side to check. ... The Sperry walking sticks will do this in a oner (Int: 07).

Diagram 7 - 4 depicts how manual probes and early walking stick probes missed the gauge corner. It also shows where the operator shifted the probes to get a fuller coverage:

⁶⁴ Taken from Int: 25.

⁶⁵ For a description of the procedures used with this system see Railtrack, 1998b: RT/CE/S/055: Rail Testing: Ultrasonic Procedures.

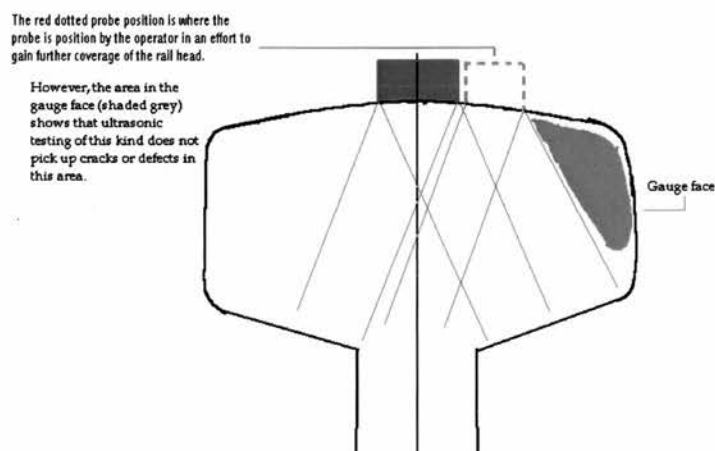


Figure 7-4 Missing the gauge corner (author's sketch).

A new walking stick has been introduced recently which addresses this problem: the Roller Search Unit (RSU), also known as 'The Sperry'⁶⁶. This uses a testing method known as the U14 procedure. This walking stick has replaced the earlier sliding probe with a rotating wheel arrangement, using three forward and reverse looking 70-degree probes and a 0-degree probe, which allows the total rail profile to be tested in one sweep. "This is a major advancement in the ultrasonic testing of rails and, in particular the detection of serious RCF defects at the gauge corner" (Brentnall, 1998: 28). The impact of the Sperry is clear:

Issue two [of the PWSI4] categorises RCF on surface length and, based on surface length only, a speed restriction is put on or not. In issue three there has to be an ultrasonic indication to put a speed on, so they've moved on, that's a good step.... But that's on the assumption of the Sperry walking stick. If we find a long crack length we don't have to put on a speed restriction immediately but we have to UT it within 36 hours. But no UT indication, no speed restriction goes on. (Int: 03).

⁶⁶ So called after the name of the manufacturing company that designed and manufactured the device.

The Sperry, also known as the "Walking Stick" or the Roller Search Unit (RSU), and the operation of which is referred to as the U14 procedure.



Figure 7-5 "The Sperry" or the "Walking Stick" (author's photograph).

7.1.5 Confidence

The confidence in UT and its importance has developed significantly over the past two to three years. Speaking before the introduction of the Sperry, workers suggested that the discipline required progress:

Traditionally it was just a signal system, there was only one way to test the rail, and that is unlike other industries which have many ways to test for cracks... In the nuclear industry and others, one test complements the other... the results are compiled together. It's done that way. ... In the railway industry, I think the entire [UT] system needs overhauled; you can run [the bi-directional sticks] up the rail that direction and test ultrasonically, find something, turn around and test the other way, and then find nothing... in terms of accuracy, you can't measure a defect, the tests are not repetitive, no sensitivity, then repeatability? You can test at 2am then four hours later test again and get a different result (Int: 12).

Where another simply said the UT in the railway industry was in "its infancy" (Int: 05). Still, the Sperry was a response to the worries noted by Int: 12 and now confidence has grown. This confidence is captured in the PWSI4s. In the first PWSI4 there is a section entitled: 'Guidance for Ultrasonic Testing in RCF sites'. The section is limited to approximately one page of the document and raises 12 individual matters concerning UT inspection. In the latest PWSI4 (Network Rail, 2003), again a section

is given the same title but it now fills three pages and highlights 29 specific points that the UT operator must be aware of.

The technical reliability of ultrasonically testing the rail has evolved. For example, in PWSI4, issue one (Railtrack, 2001e), an instruction states that an RCF site that has been categorised as 'heavy' (cracks between 20 and 29mm long) but shows no UT flaw indication, must be retested using the same method within 4 weeks. Yet, this time limit – in PWSI4, issue three (Network Rail, 2003) - has been increased: the same site now has to be inspected within two months. Effectively, it has been possible to increase the retest time, as reliability of the method has improved.

7.1.6 Developing technology, changing perceptions

The progress of UT in recent times has had an additional effect for those who operate the equipment. It was suggested that, in the past, the occupation had an unfavourable reputation because UT operators are employed to look for faults that need to be fixed by others. The very nature and aim of the ultrasonic operator's work, from the very start, was designed to find work for others. Ultrasonic technicians are not problem solvers but problem finders: this is exactly their safety critical role but other workers it was suggested, looked upon it differently.

The feeling about [UT] operators... they were just not wanted... there was a lot of aggression between ultrasonic operators and fixers. They're never seen but they were always felt, but the guys never felt wanted. Ultrasonics was seen as a black art, they tended to be given a patch of work, defects were reported and some paper work would come in... it was something that just happened, it threw up the odd defect and problem (Int: 03).

Ultrasonics! [said with a discontented groan]... it was seen as an additional test, that it wasn't hugely important. It was seen as a pain in the neck, Maintenance Engineers would have to re-do plans because of ultrasonic tests (Int: 05).

People panicked when they saw them [ultrasonic operators] – "*Oh no, what have you found, you're not putting on a speed restriction*" – because that's what no-one wants. Ultrasonics finds jobs for people, and they're not pleased, but what can we do, we're only doing our job (Fw: 02).

Historically, ultrasonic operators worked alone⁶⁷, they were always seen as the ones who don't fit in with a group, the PWSM doesn't want the ultrasonic operator to find anything, he creates work for him (Int: 01).

Still, perceptions of UT are changing (not least because of the Hatfield derailment) and, as a consequence, there has been a marked difference in the staffing levels of UT operators:

Since Hatfield, ultrasonics has been highlighted... since privatisation there was no consideration of the WRI [wheel / rail interface], but there's increases in braking forces and so on, so your wearing out your asset faster, so you need to inspect more, there's been an increase from about 200 UT operators to 500 since 2000. Historically, UT was viewed as... not extremely important... I mean, there was 30 years or so between two major incidents, Hither Green [1967] and Hatfield [2000] (Int: 25).

In this section we have been given an insight into the role of UT, its technical progress and we were given a glimpse of the requirements placed on the UT operator. In the following sections, I analyse the actual activity.

7.2 IN PRACTICE: ULTRASONIC TESTING ON SITE

7.2.1 Preparing to go on site: the meeting point

I have condensed and connected numerous pieces of observations from fieldwork notes that, in total, span several nights and days when I was involved with ultrasonic testing (UT). This has been done to give as accurate an account as possible of the working life of an UT operator and a UT team.

⁶⁷ He is referring to the Audigage system – which involved the operator wearing a device similar to headphones to hear the sound from the tapper on the rail. This of course meant the operator had to work alone.

Alex has organised it for me to meet up with a worker involved in UT of RCF sites. I meet him at the permanent way hut at the back of a mainline station at 11 p.m.

I turn up at the appointed time. There are three maintenance company trucks where I am due to meet Mark. Each vehicle, whilst capable of carrying equipment, also has seating in a cab capable of taking about 6-7 people. I see four people dressed in jeans or tracksuit and wearing fluorescent jackets with Railtrack emblazoned on the back. They are standing in the darkness talking. I approach them and ask for Mark. *"He's ultrasonics isn't he?"* says one guy to the other. He has not arrived but, I am shown the hut where he will go when he does. I wait in the darkness. The only light is from streetlamps and the vans in the yard. It has got quite busy; over 20 different people are now shifting "STOP" signs, clamps and drills into the back of trucks, it has also got quite noisy. I have been here in this yard before, but that was during the day and it was much quieter. I see someone entering the hut where I was told Mark would go.

I stand in the small hut with Mark. Though they refer to it as a hut, it is actually a room of a large building (about 12feet long and six wide: I guess that a full size billiard table would fit in snugly). Inside there are filing cabinets and numerous metal shelves. On these are pieces of rail used for calibrating gear. There are also ultrasonic packs (digital packs: i.e., new ones, and analogue packs). There are rows of batteries being charged for the digital packs. Beside these rows of batteries is a dirty kettle. Below these shelves there are UT walking sticks. Two of the four walls hold shelves, at the third there is a large desk hidden beneath layers of papers. There are also inspection frequency charts, and names of workers and phone numbers below an underlined supervisor are listed. There are two calendars both featuring topless women. Between the door to the room and the desk are five tall metal lockers; blocking access to the lockers are numerous tall rectangular cardboard boxes – used to send faulty equipment back to York (Fw: 01).

The numerous empty boxes for faulty equipment remind me of what another said:

The guys achieve about 80% of what they have to do. The reliability of the equipment is a major issue, two walking sticks a month are sent back to York for repair (Int: 07).

Back to the hut:

A fluorescent tube lights up the entire room. Given the amount of material in the room, and the size of the room, there is not much space left to manoeuvre yourself. Mark rummages through the papers on the desk and, after collecting some together, and after reading a memo, he tells me about his work and the importance of calibration (Fw: 01).

7.2.2 Preparation and calibration

During an interview in the same hut, a worker gave me a clear idea of the importance of calibration:

R: [In the permanent way hut] there're sections of rail with flaws manufactured in them, when waiting on a possession the guys calibrate the gear on these sections in the shop. Sometimes the guys can go a couple of months without finding a defect, so we use these to test.

I: Is this a safety mechanism, to make sure the gear is working?

R: Yes, it's a standard we have to work to (Int: 04).

During another interview a respondent, again in the same hut, tells me more about calibration:

Before the guys go out onto the site they have to calibrate their gear: by calibrating their gear in the shop they are making sure that the instruments are working and picking up the right signals from the sections of rail and calibration blocks that have flaws manufactured in them. Some of the rail sections have been taken directly from the railway network after the discovery of faults. ... They calibrate their gear so that each UT procedure picks up the relevant defect (Int: 05).

What follows is my interpretation of how calibration is done for one procedure: the detection of taches ovales. Taches ovales and horizontal or vertical defects are searched for with the U3 procedure: before going out on site the guys calibrate their gear on a section of rail that they know has a tache ovale in a certain position (see fig. 7-6).

To understand how the rail flaw looks like inside, the respondent showed me a thin piece of steel that was the shape of a rail profile. Just where the black mark is on the picture opposite, is where the respondent coloured the thin steel profile.

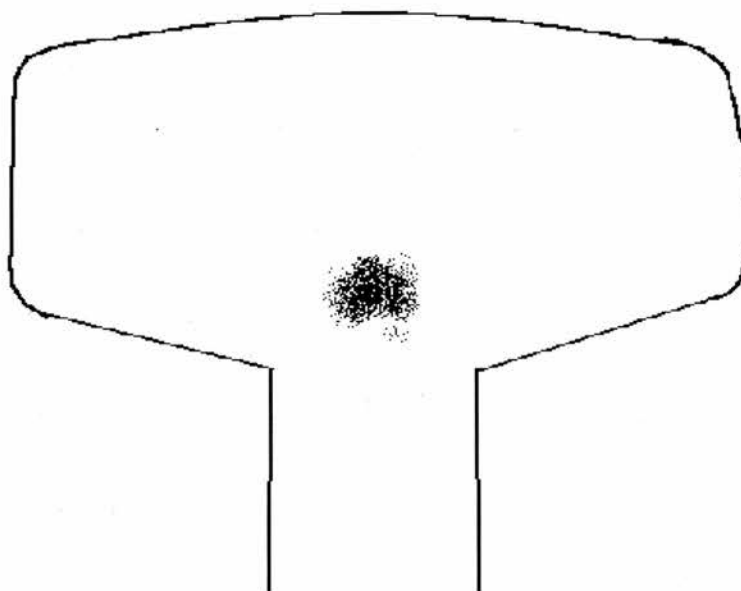


Figure 7-6 Explaining the location of an internal defect (author's sketch).

The sectioned rail above has a defect in it (the dark patch). This defect's position is known to be "40% full screen height" (FSH), and it is visualised as such onto a display screen that records what the UT probes pick up as shown in fig. 7-7:

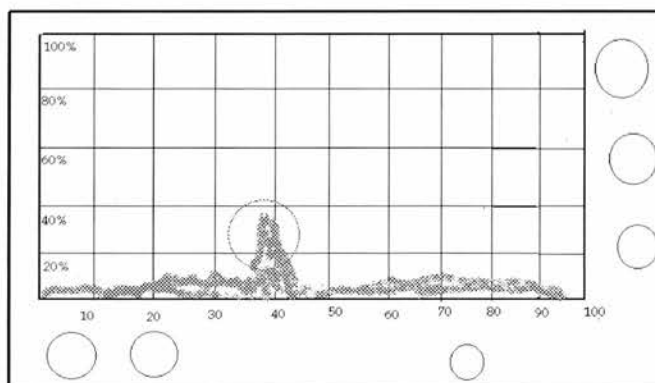


Figure 7-7 Example of a UT reading on a cathode ray tube (author's sketch).

Now because the UT operator knows that the flaw within the rail is "40%" he has to adjust the sensitivity of the reading on the cathode ray unit by turning a dial to make it read 40% full screen height (this is the calibration process). Once the flaw is read as 40% he knows that the gear is calibrated. The reason for calibrating is this:

Anything that reads over the calibrated measurement of 40% FSH in this case [when testing for a taches ovale] would be a defect that would demand a response of some kind: retest within 36 hours, clamp and impose a speed limit, retest in 7 days, or remove the section of

rail within 36 hours. ... If anything is found below 40%FSH, an audible alarm is activated to draw the operator's attention to it (Int: 05).

There are different procedural responses, depending on the severity of the problem. A defect that reads 50%FSH, (see "A" below, in fig.7-8) means the rail would be clamped and retested at a set frequency. If the feedback read 100%FSH (see "B" in fig. 7-8) the procedure would be to clamp and remove the section of rail within 36 hours.

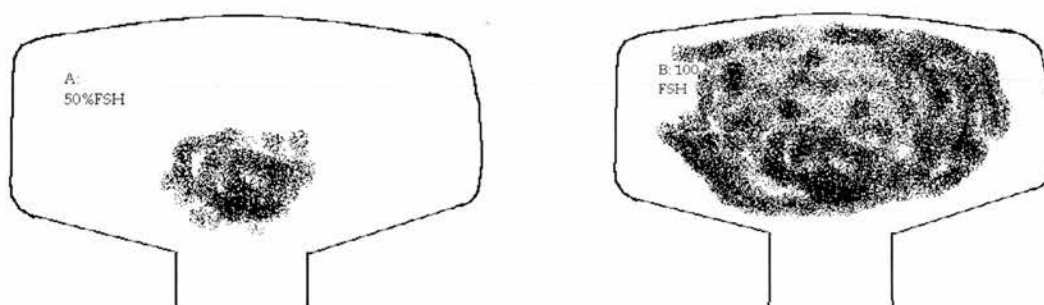


Figure 7-8 Example of fault severity differences (author's sketch).

The problems in fig. 7-8 would look like this (fig. 7-9) on a cathode ray box respectively:

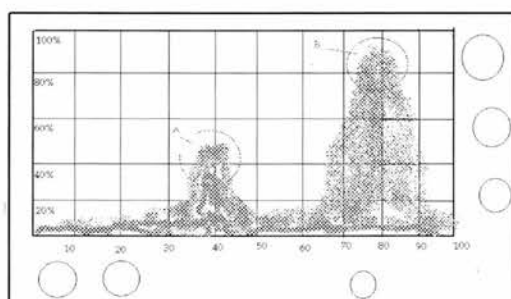


Figure 7-9 How the flaws in fig. 7-8 would be represented on cathode ray tube (author's sketch).

Whilst in the permanent way hut I was shown an example of the technological strides that UT has taken in recent years. New digital packs brought in to replace the old cathode ray tubes are sitting out on a desk.

R: They're expensive, about five grand each... I don't like them, they encourage you to be lazy. It already has stored in it the different calibrations for each defect type.

[Observation: The respondent switches one on and my understanding is this: you turn a dial to switch between different calibration types. The calibration is displayed on a digital screen and a sensitivity level is also set by default, but the operator can change it to make it 2-3db [decibels] over sensitive...]

R: ... Experienced people tend to work oversensitive...

[...and the feedback, once the probes are placed on the rail, is displayed on a table / graph-like display. There is continual “noise” on the display at the bottom of the graph, and when a defect is found an outstanding point rises from the noise].

In the opposite picture a new digital display is shown. It is attached to a walking stick.

The “peak” on the reading towards the right of the screen shows a clear reading from the rail bottom. It is when this is interrupted and there are peaks to the left of the display that suggests that a fault might be inherent.



Figure 7-10 A reading on the digital display packs (author's photograph).

R: This [digital pack] can hold information on about 5000 defects. Information like mileage....

[He turns the unit around and shows me the ports at the back of it]

R: This information can be downloaded... we don't have the software, the software costs about £80,000

[This is not an error; it is eighty thousand pound for the software. I asked him to repeat the price to make sure I heard correctly!]

R: The leads alone [from digital pack to probe] cost £16. A probe can cost £100.

I: How reliable is this equipment?

R: It is re-certificated every year [he shows me the small labels that are on each of the probes and on each of the digital packs and other equipment in the room]. This [label] shows when it was re-certificated, [there is a date on each label] it gets sent to NRS (national rail supplies) in York where it is re-calibrated. As long as this is done we know we're working to standard. We don't use anything outside [the] calibration, if something went wrong and Railtrack came in and checked our equipment and paperwork ... our feet wouldn't touch the ground. This is 18 years old...

[Jim draws my attention to a long -approximately 12" long- , oblong shaped item, yellow in colour, with a handle on top. At one end there is a visual display screen with several lines going across the screen horizontally and vertically to give the effect of a grid. There are 2-3 dials next to this display. It is the facing of this that I have sketched in fig. 7-9]

R: This is what was used before them [the digital packs], it's a cathode ray. I'll be using this tonight... they're robust,... feel the difference in weight between this and that [the digital packs].

[The digital pack is light; I could easily hold it in one hand. The older testing unit was very, very heavy].

R: It's [the cathode ray] still up to standard, it doesn't have any pre-calibrations in it, doesn't store any information. There's a lot more paper work when using this. Each time you test have to re-calibrate it, it keeps you on your toes. But this is the way we're going [points to the digital pack] (Int: 04).

Back to Fw:01 and, after telling me about calibration in the permanent way hut, Mark, armed with papers he had lifted from the desk, walks to the parked van to drive to the first site:

There is a seat between Mark and I that is absolutely covered in papers. Indeed the seat that I am sitting on had been covered in papers until Mark told me just to move them on to the dashboard or to the side of me. Print-outs from computers are either folded or unfolded: hand written notes are dotted around; some paper is scrunched up ubiquitously; and thin booklets and thick booklets create an unstable tower on the middle seat between us. On the dash board it is more or less the same, indeed, when Mark moves the van I have to instinctively reach out to grab falling papers. Wedged in a space on the dashboard above the radio is a small polystyrene cup crammed with pens. A mobile phone is in a holder that is pinned to dash board. Above the sunvisors there is a space that holds numerous ring binders. In the pockets of the door to my side there is more paper and, at my feet, random A4 sheets lie. Quite frankly, everywhere in the van that a slip of paper, or a book, or a folder, can be inserted, crammed or slid into, is indeed, taken up with some form of stationery (Fw: 01)⁶⁸.

The scene before me is replicated on other nights in other vans and it reminds me of the words of those in interviews regarding paperwork. Moreover, at the end of one night's work, when one UT worker starts writing up his findings and comments, he tells me:

The information we put in, it doesn't come back. I try to put in as much information I can under "additional comments" – "*RCF, longest crack length, has come back at [location name] on switch blade, or stock rail, at [S&C number]. But when it comes back to us [stating the inspection frequency that the fault requires], it will say mileage, location and rail, but won't tell you if it's the stock rail or the blade... means we have to check both, or the length of the longest crack... I know the area and can remember the majority, but I can't remember each and every fault I test, I test hundreds every week!... I don't know if it's a problem with the software package... but we get little feedback. The list of faults I have to check [that he is given at the start of each week] is not even in order, I have to order it myself [in terms of location]. I don't want to be driving around the country going back on myself, or*

⁶⁸ During all my field work (for UT, visual inspection and grinding) I met up with the workers at arranged meeting points, at these meeting points we climbed into vans and headed for sites, the vans all had numerous pieces of paperwork. Albeit, the one described here from my first stint of fieldwork had arguably more paper scattered around it than all the others I eventually rode in.

finding out at the end of the week that I missed one.... That's why I spend time ordering the work myself" (Fw: 02).

Another UT operator commented:

Paperwork? There's a lot of it – I take it home and fax it into the office- it's a nightmare, it can still take me a couple of hours or so, so I'm still not finished really (Fw: 12).

The same worker then suggested that he may have actually got his job as he was more willing to work with paper than others might have been:

I: Did you have any particular experience with RCF / gauge corner cracking identification [to get this work position]?

R: Not really, I had just as much [experience] as the other guys before Hatfield. I mean... everyone had seen a bit of it, it was just [name] wanted me to do [this job]. There's a lot of paperwork with the job, maybe that's why, maybe it would put the other guys off. ... No disrespect to the guys, they're good at their job, they just don't want the paper work (Fw: 12).

7.2.3 Getting on the permanent way

The first site we are going to is due for a six monthly retest. It's on a curve where RCF was reported, in response the site was ground, and now, six months later, it is time for a visual and ultrasonic inspection.

Mark phones the PICOP [person in charge of possession]: "we can get on 00:55". Mark tells me again how he should be booked into a possession, "that's Alex's job, he should have me booked into every one, but he doesn't, but I know the PICOPs so it's no bother. I tell Alex that I must be booked into a possession on Saturday night – that's the busiest night, and I should be booked in just to make sure" (Fw: 12).

On another occasion I heard how access to a possession is granted:

"I'm on first name terms with all the PICOPS in this area, I can get in.... the PICOPS tend to be all agency guys from [company name] ... It could be a problem if you're not booked into a possession, but I know the PICOPS, they're like... 'aye ok, on you go'. Any new person won't get on, the PICOPS, you know... 'and who are you?!'. I don't blame them, I wouldn't let any one on. [Person's name] should plan

possessions. There used to be T2Xs, [possession between traffic], this doesn't happen anymore, everything has to be planned" (Fw: 02).

Back to Fw: 12: it is 00:55.

We climb a fence, get in to the 4-foot and walk to the site which is found quickly - the database reference number for this site is painted on a sleeper and is faded, Willie re-writes it with a tin of spray paint whilst Gordon switches on the walking stick. Before Willie walks with the stick Gordon walks on ahead to visually inspect the rail. After Willie has made sure the water couplant is getting onto the rail and he is getting the rail bottom signal, he and I walk along the line with the walking stick. He tells me what he is looking for.

Along the timescale, marked 00 – 200mm, he says "*you should always have a rail bottom signal*" – a signal near 80%FSH near the 160mm division. That means you are getting an "*uninterrupted signal right through the rail*": no defects or faults are breaking the signal. If there was something you would expect to "*see something about the 20mm division, something quite shallow here because this site has been ground recently*". But mainly, what you are doing is *looking for a loss of rail bottom*. *You have to keep the walking stick centred, if you go too far to the edges you get a signal of about 40mm – the first time you see that you might think you've got a problem, but it's not – it's the underside of the rail you're hitting – so you have to keep it centred* (see fig. 7-11).

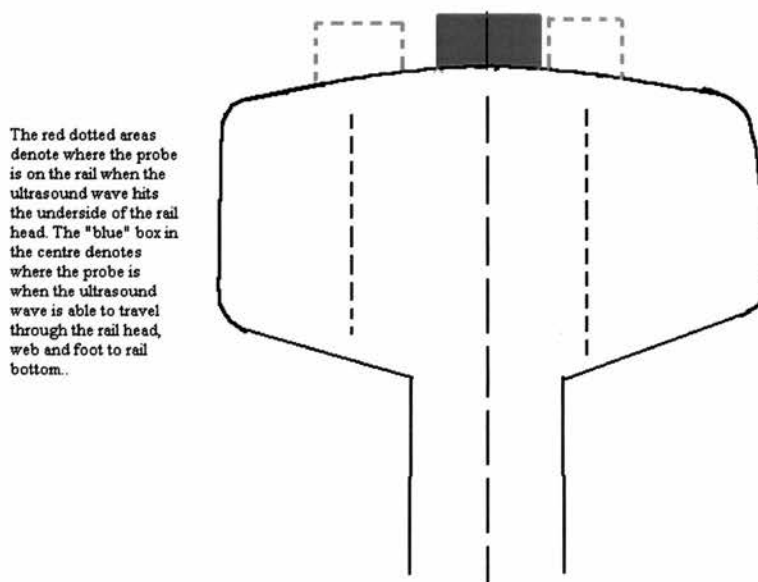


Figure 7-11 Hitting the underside of the rail head (author's sketch).

I ask Willie about the skills he needs when operating this machine. He tells me *"it's pretty basic"*. He came from the oil and gas industry and he's worked on submarines – ultrasonics is his thing- always has been - for 23 years. But *"this is just rails – it's straightforward"*. You do need *"a bit of interpretation, but that comes with experience – you know when your hitting the underside of the rail head – you know when to centre up again, you know when the couplant is not working – you get to know these things"* (Fw: 12).

In this example we got to the site at 00:55 without any delay, this however, was not typical. Signalling problems and late traffic often means a lot of hanging around for workers:

A railway station is in sight to our rear and on the line to the north, there is a vehicle of some type. The bright lights of the vehicle make it hard to distinguish exactly what it is. It is also hard to determine whether it is moving or not.

Mark, with clipboard, takes our PTS numbers and tells us exactly where the site is; he tells us to look out for the "usual" hazards underfoot: loose ballast and debris. He asks one of the men if he will be the first-aider.

Mark then leaves us to speak to someone. The two other men in the team and I stand together and speak...

After speaking for some time, perhaps 20 minutes or so, Mark approaches and joins in the conversation. The conversation continues; it goes on for some more minutes, nearly a quarter of an hour passes. I am curious as to why we are not going on to the track, and why no-one has spoken about this time we are spending just standing here talking and not getting on with the work. The conversation between the three of us tails off with still no reference as to why we are hanging about. As much as I want to ask why we are not working, I also want to wait and see if anyone mentions this period of inactivity. Because no-one talks about what seems like wasting time I guess that this perhaps occurs frequently. Despite my curiosity, I continue to hold my tongue. Mark wanders aimlessly around, so do the other two men. I find myself occupying my time by walking on lengths of unused rail, testing my balance. I also shine my large, powerful torch on objects far way. Time is passing. It's nearly an hour since we got here, nothing is happening, other vans arrived some time ago, some of the occupants are perusing The Sun and drinking from flasks. Thankfully it is

a nice mild night.

I can't stand it anymore, I ask the obvious question: "*Is there a hold up?*" Mark tells me the PICOP is not letting any one near the track because of the large vehicle that is stationary to the north of us at the station. I find out that this machine is used for tamping (realigning the ballast). Mark tells me that the signaller in charge of the signal that is at red in front of the tamper will not change it until the line further south is clear. Mark tells me that this sort of things happens often. "*What can you do*" he says with a hint of resignation. The tamper "*only moves at about 5mph*"⁶⁹, *you're going to see it coming, and hear it. But we all have to be on the side of safety now.*"

It's about an hour and a quarter since we got here and eventually the tamper moves off. There is a burst of working activity before us...⁷⁰ (Fw: 01).

It is to some activities that we now direct attention.

7.3 GETTING TO KNOW THINGS: FIVE EXAMPLES

7.3.1 Example one: experience and decision-making

In Fw: 12 the worker said of UT inspection: "you get to know things". But what did he mean? - How do you get to know things? It will now be shown that getting to know things is often a tacit, complex process that relies on informal training, group discussion, collaborative learning, experience and know-how, interpretation and imagination.

I ask Jim about the role of experience when doing UT. He points out to me how "*you have to be wary when relying on the audible alarm. There is a three second delay;*

⁶⁹ Tampers can actually move significantly faster than this. They can move at 40 – 60mph between tamping – meaning there is a safety risk

⁷⁰ Such delays, like the one just described, occurred on other occasions and could be given as a preface to most field-notes however, but not wanting to write repeatedly out boring uneventful waiting, I think it is sufficient to give one example and to simply note that delays in getting on to the track were common during my research.

you cover the defect, then the alarm sounds but because of the speed you're walking, if you look down then, you will miss it. You have to retrace your steps and scan the rail again and look closely. That can be a danger, but you should always be looking at the display screen in any case' (Fw: 16).

Understanding the operation of the machine is an obvious pre-requisite, but understanding the environment of the permanent way and being able to dismiss spurious factors is also required:

"Patterns on rails can be confusing". Jim points out an area of rail that looks damaged, but isn't. It is simply because of "diesel or something else that has been picked up by the wheels and has made the rail look like that, you can tell the difference through time".

We are at two switches and crossings and despite exhibiting light RCF, there was no UT indication. Whilst here, Jim tells me that UT operators must be *"wary of the rail's shape"* when testing. For instance, here is a rail that has been transposed, and the field side (i.e. what was once the gauge corner side) is well worn down and is affecting the rail depth reading. Instead of being approximately 160 it is at 120. Just reading the display alone would have suggested a problem. He says: *"when you're at the training centre they do point out things like this to you, but still you have to see on site with guys who already know these things, that's how you learn. These little things are important"* (Fw: 16).

7.3.2 Example two: hand held ultrasonic testing of bolt holes

I am following a UT worker whose task is to test for bolt hole star cracks at fish-plated joints, see fig. 7-12, that is the cracking that caused the Hither Green derailment. The calibration for bolt holes is 80% full screen height.

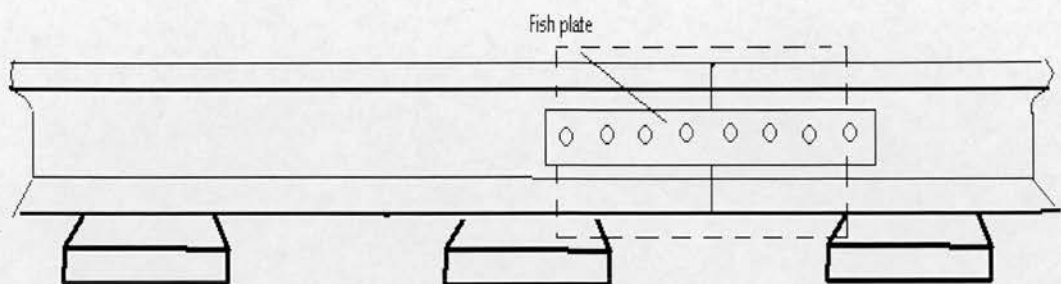


Figure 7-12 Ultrasonic testing at fish-plated joints (author's sketch).

Star cracking at the bolt holes through the web of the rail can occur and this is called because of the crack shape. In Railtrack document RT/CE/S/055 (Railtrack, 1998b) each bolt-hole and star cracking is lettered⁷¹, see figure 7-12. It is the detection of these cracks with hand-held probes that the following example is concerned with:

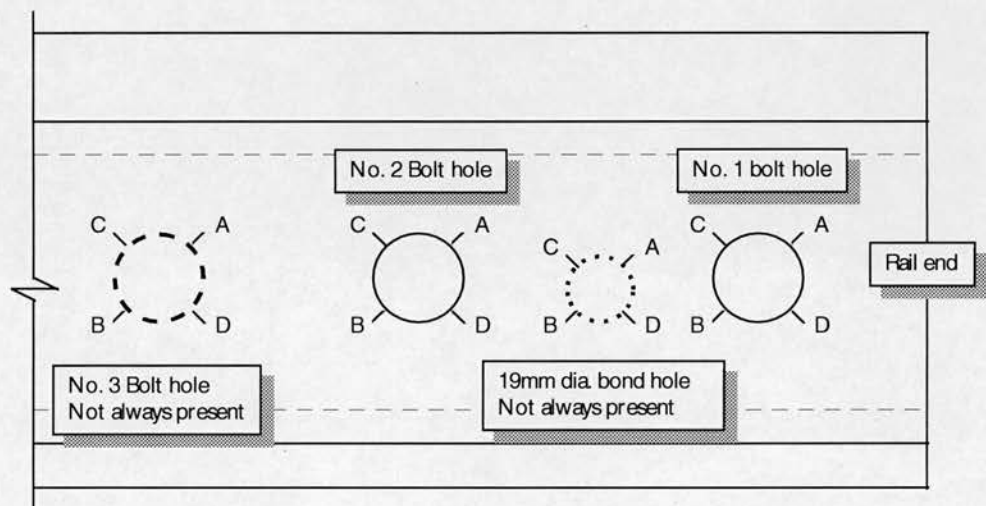


Figure 7-13 Star cracking (RT/CE/S/055, Railtrack, 1998).

⁷¹ All crack positions except 1D and 1C: Place the probe at the start line and pointing towards the bolt hole. Obtain and maximise the signal from the bolt hole as the control signal and set this signal to an amplitude of 80% full screen height. Move the probe backwards until the control signal disappears. If a crack is present in the B/D position the signal from the crack will maximise at a longer range than the control signal. Move the probe forward to its original start line, ensuring that the control signal returns to 80% full screen height. Continue to move the probe forwards until the control signal disappears. If a crack is present in the A/C position, the signal from the crack will maximise at the same range as the control signal (Railtrack, 1998b: RT/CE/055).

In all cases when the control signal disappears, the probe must be swivelled on its axis to search for the presence of any defects at the sides of the hole. This instruction also applies to the following scans.

Neil and I walk to the first fish-plate, where he sprays the surface of the rail with water before running the probe over the centre of the rail. He starts at the end of the fish-plate and heads towards the rail end. We see the first bolt-hole – the reading comes up on the digital display between 100 and 120mm and is between 80 and 100% full screen height. *"I've calibrated it so it would be higher than 80%, that way you can see it easier. Sometimes when it doesn't read as high as 80%, it can be because of wear on the surface of the rail head, you've got to look out for things like that. But then send in more sound just to make it 80%. Then test it again but slower to see if anything is there"* (Fw: 11).

Manipulating the machine to suit the conditions of the worn rail was done here for effective UT. But looking out for a worn rail is not as simple as it may sound. A keen well-trained eye is required: this is because a rail that has suffered wear can be worn by only a matter of millimetres.

Now, despite the fact that Neil pointed out that the rail he was testing was worn, I simply could not have said from my own observation: *"That rail is worn"*. Perhaps if there happened to be a brand new rail with no wear lying parallel for me to compare it with I might have noticed the difference, but there was not, my eye was untrained in the skill of recognising wear. To find out these things Neil spoke about on-site learning; *"Another [in the group] will always be there to tell you if things are fine or not"* (Fw: 11).

When we are walking Neil tells me about the importance of discussions:

"If there is something we have not seen before [on the visual display] – say a signature duplicating exactly the first, you might at first think that there is a fault. You're getting a double kick, but you realise, someone will tell you it's ok; the bolt is too tight and you're getting a double reflection of the bolthole" (Fw: 11).

At this moment, Neil then gives an example of the decision-making process that can occur within the group. Later, he also refers to a collaborative learning process that calls upon the experiential knowledge of others:

"But if there is something strange, the guys have a conflag – we discuss things and get the probes out, and if we're still not sure we take the bolts out and take the

plates off to look at it visually. Then we can see if it has been drilled or bored badly or if the bolt is too tight and is catching the ultrasonic wave"(Fw: 11).

Do UT operators learn such things during training?

At Derby [location of the training school where all UT operators for Britain's railways are trained]: *"you practice on rails with very clean boltholes, and definite faults. So you can see the difference. But when you're on the site, things are not always that clear"*. Another in the teams said: *"The first time I saw something like that I thought crikey, got a fault here, but you find out it's otherwise. Sometimes, the way they've battered the bolt – it can cause a slight chip and you can get a reading of that. Even though you do the course a Derby and they assess you and you pass your test you still learn on the track"*.

Neil goes on to tell me about the noise that runs up and down the timescale at 00mm to 40mm (See fig. 7–14). He says that this is when water drips down the rail end or when the join is too tight. *"See here... [he points to a specific area between two adjoining rails] that is tight. The biscuit [the name of the pad between the rails] is squashed, sometimes you get a kick off that when the sound waves runs up and down it, and that's what it looks like on the display [the noise between 00mm and 40mm]. You get that noise, but again that is something you learn from others"* (Fw: 11).

The role of the group and its dynamics, in the sense that team members tacitly learn from others, is clearly essential, but not just for any new-comers who have to rely on the experience of others when learning how to make decisions. A solid structured group with a shared sense of responsibility is a must:

They're learning from experience, they're a good bunch of boys... there's different types... the impatient one... the thinker that questions everything, and the one who's a bit of both, the balance. ... They look out for each other, that's good. It's important to have that. They discuss the problem, and they agree on the final action. ... The lads have to be interested in their work, if they come to their work with the aim of just getting finished, that's no use... they have to be interested because it depends on their interpretation of that screen (Int: 05).

7.3.3 Example three

We now have an inkling of what operators look for, and what skills they rely on when testing. We now look at these skills in action.

We get to [the site]. It's a complicated looking set up of tracks and switches and crossings: there are four main lines, two of which are fast -100mph, and two are slow - 40mph. Coming off each line there are subsidiaries that are also slow. So there is a lot to know when considering where the traffic is coming from and how fast it will be and where the position of safety is.

EXPLAINING NOISE



Uninterrupted rail
bottom signal,
thus pointing out
that there is no
problem.

This feedback at the bottom of the display is "noise", if this noise "climbs" the left hand side of the display to approximately position "A", this suggests to the operator that the signal is reflecting off the rail edge and pad (known occasionally as the biscuit).

Figure 7-14 Explaining noise on the digital display packs (author's photograph).

What makes it all the more treacherous is that it's been snowing; the sleepers are extremely slippery underfoot; each step is taken with caution. Each one of us now and then, slips and slides, but we regain our balance. There are five sites to look at here, four of which are at S&Cs. The other is in a plain line (CWR).

It takes a bit of searching to find the first S&C, the number [of the S&C] is written on top of a large plastic container but beneath a layer of snow. So we have to walk to each S&C and scrape off the snow until we find the one we want.

We find the first fault. It's a 100mm crack, yes – one hundred – and when measuring it we see it hasn't grown. As Eric puts a metal rule against it, the men decide not to UT it simply because it has not grown and it has no UT reading history. But Eric and Dougie both agree that this crack is not true RCF, the area on the rail around the crack is full of wheel burns. Eric tells me, "*technically, that's not RCF, it's wheel burns, but someone first reported it as RCF, so we have to check it as that.*" Eric is convinced the crack is only along the surface of the rail.

We have to clear the track, a freight service with dozens of wagons full of coal go by. "*That's the boys that cause all the wheel-burns*", says Dougie. "*When they pull away all the wheels slip*".

We get back on the track and search for the next S&C. Apparently there is a crack on the rail head that is 10mm. After a bit of time searching I see the 10mm mark on the foot of a rail in yellow crayon, I point this out to the men; this is indeed the crack that we should be checking. It's in the field side of the rail, and it is relatively easy to spot for someone has already scraped the rail, so against a rusty looking background there is a silvery area that highlights where the crack is.

I mention how this seems a little unusual: one isolated crack on the field side, when often there are clusters on the rail on the gauge side or on the head. "*That's the way it goes, there's just no pattern to it*", says Dougie. Eric measures it with a metal rule; it's grown from 10mm to 12mm. Again I couldn't see where it started and finished. It was too difficult to see as it went into the rusty looking part of the rail. John notes down on a small bit of paper that this crack has grown. Earlier he had noted how the 100mm crack had remained the same.



Figure 7-15 The 10mm crack I found (author's photograph).

We then cross some tracks and make our way to the area where we think the next S&C is. A train passes, it is a high speed passenger train, and though we know that it is not on the track we are on, and is actually quite a bit of distance away, we make our way to the point of safety and watch it go by. Back on the track we get to the area and scrape away the snow to see the S&C number. We've found it. The crack we're looking for is 35mm long. We find it quickly, because, again on the web and foot of the rail it had been marked in yellow crayon. This crack was not in isolation; there were other smaller cracks around it. Eric gets the rule out and measures it. I'm by his side and this time I can see the crack quite clearly and, immediately, I say that it looks like it has grown. Eric agrees and says it has grown from 35 to 48mm. Eric and Dougie have a small discussion where they mainly refer to the shape of the crack and some shadowing that borders it, but the majority of the time they are in silence. They look from one angle then another and often they touch the rail. After a thoughtful moment they decide they will check it out again tomorrow for they are back in this area then and the weather might not be so bad. The underfoot conditions might not be so slippery and it might not be too difficult to carry the UT equipment down a slippery flight of wooden stairs and over a few tracks. In the end they decide to wait till tomorrow.

At the next S&C there's a 10mm crack on the stock rail. We find it simply because it is marked brightly with yellow on the rail foot and web. The same procedure is done

with the metal rule. It's grown also - from 10mm to 18mm. This crack is isolated. Alec says it has grown into an "L" shape. Alec and John have a look at it. Though it has grown they do not appear to give it the same attention as the last crack that had grown. They note it, and go on their way to the next site.

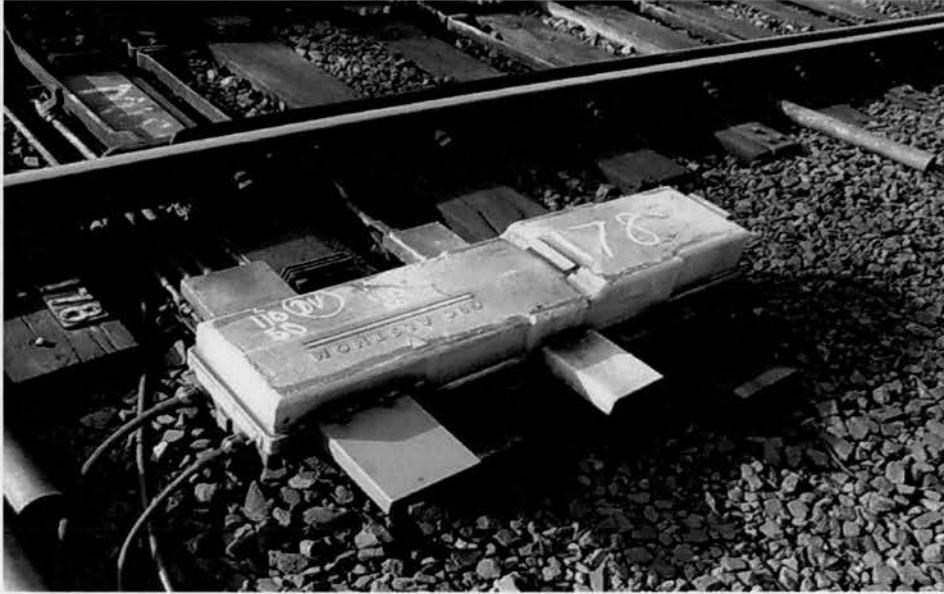


Figure 7-16 How an S&C is labelled (author's photograph).

Though the sites have been tested, Eric and Dougie still seem unhappy with the crack that had gone from 35 to 48mm. Before heading to the van, they pause and though they haven't spoken about that crack since they measured it, they seem to have it at the forefront of their thoughts for they have both looked in the direction of the S&C that was affected. When looking at the S&C from a distance, and as if knowing what the other is thinking, they decide that instead of waiting till tomorrow they will get the walking stick down and have a look at it now. Eric goes back to the van, and drives it closer to the area and comes down the wooden steps safely with the equipment.

At this moment I talk to Dougie about the hassles involved in searching for faults. He is not convinced that inspecting rail at night is correct: *"many [faults] must go undetected"*, but adds; *"they don't mind how it's detected, as long as it is looked for."*

If anything happens, but we can prove that we were looking for it, that's ok". Eric approaches us with the stick.



Figure 7-17 An example of how a crack is labelled on the rail foot (author's photograph)

The stick is put on the rail and the probes are connected up to the pack. Dougie runs the stick over the fault. There is no reading; the signal from the rail bottom is clear and not disturbed. But one pass over the affected rail is not good enough to satisfy them and to make sure Dougie goes over it a few times. He manoeuvres the stick in slight ways as if feeling for something. Eric keeps an eye on the pack, as Dougie skips his eyes from rail surface to pack. Eventually they say it's clear.

We're walking back to the van over the track when Dougie stops and says, *"See, how would you spot that at night?"* Dougie noticed a series of very small RCF on a stock rail, it was very faint and each crack was only a matter of millimetres long, *"that would get missed at night"*, Dougie concludes (Fw: 17).

An implicit process occurred during these tests that relied on a degree of know-how and tacit knowledge. Specialised knowledge and being wary of some cracks and dismissing others as spurious is a necessary skill. Having an inkling as to where they will occur is another. This tacit skill is captured now:

7.3.4 Example four

Gordon has found one crack, which I eventually see myself. But again I am wary that I am looking at the rail from a closer distance than Gordon before I see it slowly emerge. I run my finger along the subtle serrated edge and then Gordon measures it with a plastic rule: *"20mm, I would say"*. Willie then ran the walking stick over it and got no signature. We then continued walking over the length of the site; no UT findings were found over the remainder of the rail. When we got back to the van Mark was filling out papers and he asked if we had found anything. We told him about the 20mm crack but that nothing was found with the stick. Mark found another sheet of paper and filled it in whilst passing the comment: *"I knew it would come back"*. I immediately ask him how he knew this: *"It's just a hunch I s'pose, but if there's been gauge corner cracking there before, it's going to come back after grinding"*. Then pausing and looking out the windshield to the permanent way we had just walked, he says: *"It's just something about these curves, it'll come back"*. I mention how it was only one isolated crack we saw: *"it doesn't matter if you see one crack or if you see hundreds, one is enough. That tells you it's back. I mean, if you were out here during the day and you walked this track you could find lots of sites, but just finding one is enough at the end of the day, cause it tells you: it's here – full stop"* (Fw: 12).

7.4 THREE ULTRASONIC TESTING SPECIALISMS

7.4.1 Interpretation, imagination, and touch

When reading the results on the display unit the operator needs to be vigilant and his interpretation must be finely tuned. Being able to distinguish between typical noise and double kicks and real faults, and between serious cracks and minor surface cracks, is a key, practically acquired skill.

Ultrasonics is a very specialised field usually left to the experts... The passage of the ultrasonic energy is not as clean as one would like. In particular, there is a disturbed zone of about 10mm at the interface between the probe and the rail [thus] the first several

millimetres of the entry into the rail cannot be exploited. But, in principle, the information given is sufficient to locate potential defects. In practice, the traces are lively and require great attention for interpretation (IHHA, 2002: 5-25).

Another UT specialist likewise suggests:

When ultrasonic flaw detection techniques are applied, a considerable amount of skill is required on the part of the operator. He must be suitably trained in order to be able to identify various types of defects from the shapes and sizes of the traces observed on screen. Care must be taken to ensure that a particular peak corresponds to a defect and is not a spurious indication (Blitz, 1971: 106).

Another refers to the operational advantages to be gained if the UT operator has significant experience:

In practice, when testing a larger object in detail, or a number of similar objects, a skilled operator can eliminate to some extent all unknowns not related to the defect, especially if there is a back-wall echo to be found, which serves as a reference. By carefully examining a flaw, and using his experience, the operator can gain a significant amount of information about it (Sziland, 1982: 45).

7.4.2 Example five

Findings suggest that effective interpretation of signals requires a certain use of imagination and a delicate touch by the operator when testing. One night a UT team let me UT a section of rail.

Team member A: *"It does require a lot of interpretation... in this industry they... they like a "yes" or a "no"..."*

Team member B: *... "And the hardest [bolthole to test] is the 'D' position..."* [recall figure 7-13)

Team member C: *"Sending a sound wave into rail is like shining a torch on a building in darkness. To know about the building, if it's a house, if it's semi-detached, if it's two floors or one, you have to move the beam about to find out. That is what you have to do with a probe on a rail to find out the details of the flaw... Sound deflects*

at different velocities off different surfaces... It's like throwing a ball off a wall, depending how you throw the ball it will bounce off at different angles and speeds".

The men then offer me the chance to UT a random section of rail. With a knee on a sleeper and a foot on the ballast and with the digital pack in one hand, I place the probe on the wet rail with the other and try to slide it over the running band. I notice a big difference already between the way I am testing and the way the men have been testing. When they test the rail the probe glides effortlessly around the rail as if it is a smooth block of ice, yet when I try it the probe sticks or shudders around the rail, then one of the men tells me:

C: "The medium matters, pressing the probe on the rail with different force can change things as well".

Just now I recall words that I had recently read in a UT text book for training operators, which said:

Acoustic coupling between probe and test object [in my case a rail] can be provided through a layer of water. For manual work contact coupling is preferred, because it gives the operator a better "feel" of what they are doing (Sziland, 1982: 43 – 44).

My technique improves a little, and one of the team says:

A: "You're looking for a pattern [on the display], sometimes it's easier to go faster over the surface of the rail; it can be easier to see something that way instead of going slow".

It is at this moment that I guess UT operators need to use their imagination if they are to understand what is going on inside the rail with the pulsing ultrasonic beam. I asked about the role of imagination, and transferring what it is the operator imagines *onto* the visual display screen...

B: *"That's it!... It's simple trigonometry really... Training is done at Derby for a fortnight, for the basics, it wasn't until the second week that I suddenly got it... I understood what was happening with the probe and where the beam was inside the rail. Until then it was all over the top of my head".*

I continue testing the rail head above a fish-plated section trying to spot patterns on the display:

A: *"When you're at the rail end give it [the probe] a little twist, it can be harder to pick up faults here..."*

I try to do so, but just when I thought my technique was improving my unskilled, maladroit manner returns. The probe moves ungainly across the rail and I lose all signals on the pack, then when I adjust I press too hard and it's just a noisy nonsense on display. But I ask more about training and how the operators *know* that you *might* have to "swivel" the probe at the rail end.

A: *"It's learned over time... swivelling it there... He, [another group member], has been doing this for five years, he's experienced, he told me things." (Fw: 10).*

Imagining what is happening inside the rail with the signal is an important aspect when comprehending the feedback on the visual display screen. Determining what is happening with the pulsing beam is the operator's touch, which needs to be delicate and subtle.

7.5 TRAINING THE IMAGINATION

7.5.1 Informal structures

The extent to which UT operators rely on practically acquired know-how skills which are developed from shared on-site experience has been referred to frequently through numerous examples, whilst others expressed it succinctly:

When you come back from Derby, you need to go out with experienced guys – there is always someone there who can help you, you always need a hand during that time – the learning continues during that time. The problem is, some of the guys in the office think that when you come back from Derby you can go out and do all these checks by yourself– it's not like that (Fw: 10).

R: Experience is important, you can't have guys just passed their test and in two weeks checking for RCF...

I: So there needs to be a structure after the training?

R: Oh yes, we've got guys who are competent in everything and guys who have just started. It's quite a good thing to have that... then new guys can always ask questions (Int: 07).

It takes three months to get the certificate, and after Derby they work with experienced guys. They always work as a group, and they assess between the two of them or within the group what the problem is, to come to an agreement on action (Int: 05).

Given these comments, what role is there for formal training?

7.5.2 Formal structures and tuning the mind's eye

The training of UT operators is a crucial part of the system of rail fitness-for-purpose inspection.

The guys go to Derby where they learn the mandatory basics⁷² [U1: Ultrasonic Testing of Fish Plated Joints' and U2: 'Examination of Locations not Covered by U3⁷³']... then three

⁷² Through time the operator can go back to Derby to learn further UT skills. The following text points out the need for further skills: "The complex nature of a rolled steel rail and the potential for failure necessitates a number of different procedures each related to a particular part of the rail, form of defect or type of rail steel" (Railtrack: 1998b:5).

months later, after they have been on sites, they're tested on these skills: then they get their certificates (Int: 05).

One UT operator told me briefly about the training set-up at Derby:

We went to Derby for a fortnight for a course that covers the U1 and U2 procedure. The first week is taken up with a lot of theory, there is some practical, but that is mostly done in the second week (Fw: 11).

During a visit to the Derby rail test centre I was given the opportunity to see how training is organised. The following notes and comments from workers are from this visit.

"Historically, this was the old BR training centre, everyone for rail testing came here, we knew all the operators, we issued the certificates, we knew every one that had a certificate". The training centre is one building of a very large complex. There is a series of small rooms which act as classrooms. In one room there are many rows of rail sections with faults. Many of the rail sections have been taken from the actual railway network. Many of the rails have been split open so the fault inside the rail is visible to the naked eye. I am told each section of rail has been mastered: the exact range of the fault inside the rail is known. It is in this room that the candidates spend most of the first week; it is where they learn the theory and it is where they are introduced to the course booklets.

This room also houses an interesting looking gadget. A sectioned rail-head made entirely out of clear Perspex sits diagonally below an instrument that can emit a red beam. The red beam has been designed to replicate the characteristics of an ultrasound wave. In the railhead and clearly visible to the naked eye is a clean cut forming a small hollow expanse that has been designed to imitate a real fault. By firing the red beam into the railhead the candidate is able to see how an ultrasound wave "travels", and how it "hits" the clear cut "defect". The instrument simulates

⁷³ U3 refers to the testing of the full rail section by the 070 rail testing system, commonly known as the walking stick.

what occurs when the UT operator is on-site and in a real occasion. The system provides the operator with an image for the mind's eye: it underpins the imagination that those operators spoke about during an earlier episode of fieldwork. As one worker here told me: "*This is a visualisation process, simulating with the Perspex you can see the lights, this gives the UT operator an idea of what goes on ... Operators test on rail pieces that have been mastered, so we know what results the guy should get*". (Fw: 25).

Spending the first week of the training fortnight in a classroom learning theory is due to a recent change:

They're trying to bring in a lot of theory now... intense theory... some of the guys might struggle. ...They're trying to make ultrasonics a recognised skill. The guys are getting PCNs [personal certificate of non-destructing testing]. It's more theory based now (Int: 05).

A training centre worker put it this way:

In 2000 PCNs came in, PCN stands for Personal Certificate of Non-destructive testing. PCNs are recognised in other industries, but a specific sector for rail testing was introduced, the skills are transferable to a certain degree (Int: 25).

The key difference for UT operators after this change is that candidates now have to learn general UT theory, rather than just its practical application to rail testing. The major and potentially beneficial difference is that candidates are now being taught some of the fundamentals of the process, but:

Historically we tested rail testers on rail alone; there was some theory with it. But with the PCN there is more general theory about UT, that's the material that can be transferred from one UT job to another. This theory involves trigonometry, it's been difficult introducing this, we've had complaints (Int: 25).

The intensity of the theory is notable by referring to the course booklets that accompany the two week course at Derby. There are two booklets: '*Ultrasonic Testing of Rail Level 1 Part 1a General Ultrasonic Theory*' and '*Ultrasonic Testing of Rail Level 1 Part 2a Sector Specific Theory*'. The first booklet is 78 pages long while

the second numbers only 20 pages. The new training content, it is feared, may have a negative impact:

Now they have brought in a national certification (the PCN), this brings in more theory... is this a good thing? It is in a way. But the guys who are doing the job just now and who have been doing it for years, they're good at it, they are very competent UT operators, but they're suddenly faced with the theory. You can't just bring it on, you've got to bring it on gradually or the guys could get lost, and some might learn quicker than others (Int: 05).

This worker suggests that UT operators, who have been in the industry for years, and who were trained on pieces of rail alone, have become very competent and highly skilled operators despite their lack of theoretical knowledge. Their basic training, combined with years of experience has produced in them a sound (tacit) understanding of the UT principles associated with rail testing. However, for them to remain in the industry, they have to be re-tested to PCN standards every two years, which involves learning new material (see figs: 7-18 and 7-19). Take the following comment:

The difficulty is for traditional guys out there who have been testing rail for years and are excellent at it, but they left school at 15, came off the shovel and are now excellent UT operators. But now they have to face equations. They have to learn more than they need to for a bit of rail (Int: 25).

Another warns:

There's a lot of knowledge about ultrasonics in general... but we, in the railway industry... you can't tell the guys everything about ultrasonics, they'll forget (Int: 05).

The same respondent then talks about qualifications, but suggests:

It's [UT technological development and progress] getting better all the time. It's improving. I've been in the industry since 1976, at first it was like, leave your brains indoors, and take the brawn outside, gradually that is changing... there's nothing wrong with qualifications... but if they had the experience also... cor-blimey! (Int: 05).

NEAR FIELD CALCULATION

Low angle compression wave probe
with circular crystal :



$$N = \frac{D^2 F}{4V}$$

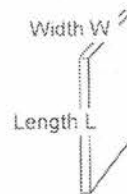
High angle shear wave probe
with circular crystal :

The modified near field distance N_{modified} is as the above formula for low angle compression probes minus the *Perspex Correction* distance.

$$\text{Modified Near Field } (N_{\text{modified}}) = \left(\frac{D^2 F}{4V} \right) - \text{Perspex Correction}$$

$$N_{\text{modified}} = \left(\frac{D^2 F}{4V} \right) - \left(\text{Perspex thickness} \times \frac{V_p(\text{compression})}{V_s(\text{shear})} \right)$$

High angle shear wave probe
with square or rectangular crystal :



$$N_{\text{modified}} = \frac{1.3L \times 0.97W \times \text{frequency}}{4 \times V_{\text{shear}}} \text{ minus}$$

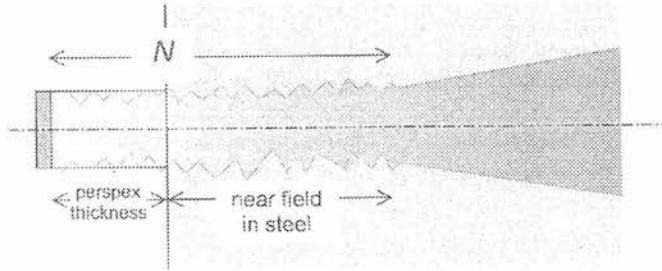
$$\text{Perspex thickness} \times \frac{V_p(\text{compression})}{V_s(\text{shear})}$$

(Note that 1.3 and 0.97 are constant factors)

Figure 7-18 An example of some UT formulae from the PCN courses books
(source: Serco, 2002b: 'Ultrasonic Testing of Rail Level 1 Part 2a Sector Specific Theory').

Worked example 1:

probe crystal 23.8mm diameter, perspex wedge depth 30mm,
probe frequency 2.5 MHz, perspex velocity 2730 m/s (comp.),
steel velocity 5900 m/s (comp.)



$$N = \frac{D^2 F}{4V} = \frac{23.8^2 \times 2.5}{4 \times 5900} = .060 \text{ metre} \\ = 60 \text{ millimetres}$$

Near Field in steel = N - correction for depth of perspex

$$= N - \left(30 \times \frac{2730}{5900} \right) \\ = 60 - 13.8 = \underline{46.2 \text{ mm}}$$

Worked example 2:

probe crystal 8mm width x 9mm length, probe frequency 5 MHz.,
perspex wedge depth 10mm, perspex velocity 2730 m/s (comp.),
steel velocity 3230 m/s (shear.)

$$N = \frac{1.3L \times 0.97W \times F}{4V} = \frac{1.3 \times 9 \times 0.97 \times 8 \times 5.0}{4 \times 3230} = 35 \text{ mm}$$

Modified Near field in steel = N - perspex correction

$$= 35 - \left(10 \times \frac{2730}{3230} \right) = \underline{26.6 \text{ mm}}$$

Figure 7-19 Another example of UT formulae (source: 'Serco, 2002b. *Ultrasonic Testing of Rail Level 1 Part 2a Sector Specific Theory*').

8 GRINDING A RAIL

All our knowledge proceeds from what we feel – Leonardo da Vinci (cited in White, 2001: 55)

8.1 INTRODUCING RAIL-GRINDING

8.1.1 Grinding out problems

Depending on UT indications, rails are either replaced if cracking descends deeply into the rail, or ground if the cracking is shallow. In this chapter I analyse the skills involved in manual rail-grinding for removal of cracking at S&Cs.

It is commonly accepted in the industry that repetitive contact between the wheel and the rail deforms the rail, whilst compressive stresses can induce cracking on the rail head. By grinding the rail, shallow cracking may be removed and the original rail profile may be restored.

The passage of wheels over the rail head removes rail head material in a process akin to grinding. Where this process occurs at a rate in excess of the growth of any defects they are effectively removed before having the chance to establish themselves. Where this is not the case, grinding of the rail head is used to achieve the same effect (Wright, 2002: Conference paper).

In normal operation the wheel grinds the rail, a process commonly known in the industry as artificial grinding. A technician referred to artificial grinding:

One of the historical things is that railways used to wear out, so steel was made harder so it wouldn't wear so easily and it takes longer for the cracks to form. It takes even more passages of trains, it's a cyclical thing. The more cycles it sees the more likely it is to initiate a crack. It's a cycle dependent thing. So because it is not wearing out anymore, what used to happen is, it [cracking] didn't form because the material was wearing away, there was artificial grinding. So now it's getting the balance: you do not want to grind too often 'cause you're wearing it away, but you don't want to leave it too long until the crack has initiated (Int: 27b).

Likewise, an industry metallurgist commented:

Hard rail ... grade 260 ... won't wear that fast, the wear rate of normal rail ... grade 220, normal rail ... is four times that of harder rail... The wheel / rail contact patch matters and the axle load. If there is good contact there is far lower stress and it will crack less. But if it is soft rail and there is a mismatch between the wheel and the rail it will wear fast (Int: 22).

When grinding out shallow cracking, the profile of the rail and the running band can also be adjusted, (see fig. 8-1):

In the practice of "profile grinding" the head of the rail is re-profiled to control the location of contact between wheel and the rail" (IHHA, 2001: 5-58).

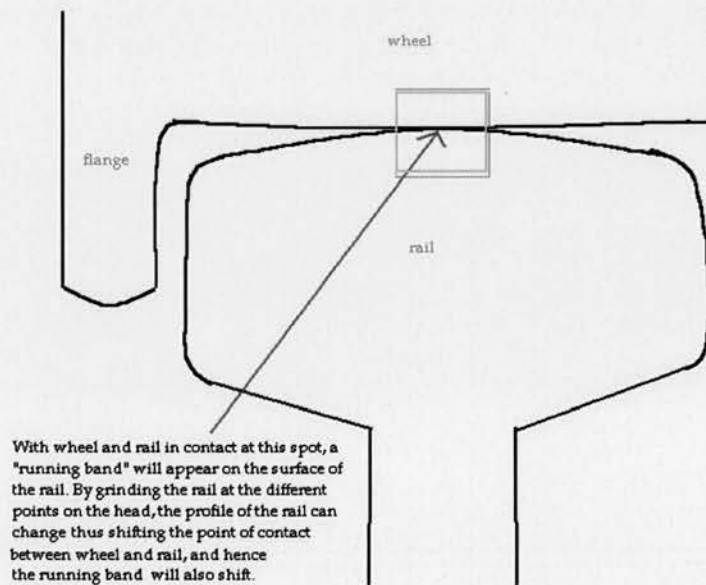


Figure 8-1 The wheel / rail contact patch and running band (author's sketch).

This means that the running line can be moved:

Away from visible cracks, [this] can stop cracks growing even though they are not fully removed by grinding (Railtrack, 2001a: 13).

The latest PWSI4 (Network Rail, 2003) also says:

Where RCF exists, grinding of long sites should be undertaken using a grinding train so as to produce a uniform running band towards the crown of the rail and to relieve load from the cracked area and slow the development of the existing cracks (Network Rail, 2003. 10.5).

Grinding acts as a form of control of the processes of rail surface fatigue and metal movement. Thus grinding is commonly undertaken by railway infrastructure owners in different countries around the world:

In-track rectification by grinding is a standard maintenance activity with modern railways... it has become a routine remedy for deformation of the transverse rail profile and, increasingly for deterioration of the rail surface and sub-surface (Schoch, 2002: Conference paper).

Accordingly, Network Rail wrote:

Rail grinding is widely recognised as the principal treatment to control RCF and other rail head irregularities. Rail-grinding will be undertaken as a preventative maintenance activity on a planned cyclic basis (2003: 10.1).

The majority of rail on the British network is ground by a 64-stone grinding train. This controls and prevents cracking:

- (1) The rate of crack growth will be retarded, allowing cracks to be progressively removed with subsequent grinding passes (Network Rail, 2003: 10.7).
- (2) [Train based grinding] will provide an improved profile and remove the fatigue damaged surface layer and reduce the rate at which the profile deteriorates. The profiles, frequency and minimum metal removal rates have been developed to slow down or stop the rate at which cracks initiate and grow (Network Rail, 2003: 10.8).

The train-based grinding system is only used on plain lengths and curves. It cannot be used at S&Cs because, the majority of S&Cs have rail which is not vertical but at an angle⁷⁴ (see fig. 8.2). Therefore any grinding at S&Cs is completed manually by teams of hand-grinders.

⁷⁴ Rail at S&C that is inclined is known in the industry as 113 lb / yd (pounds per yard). Rail that is not inclined but vertical is known as RT60

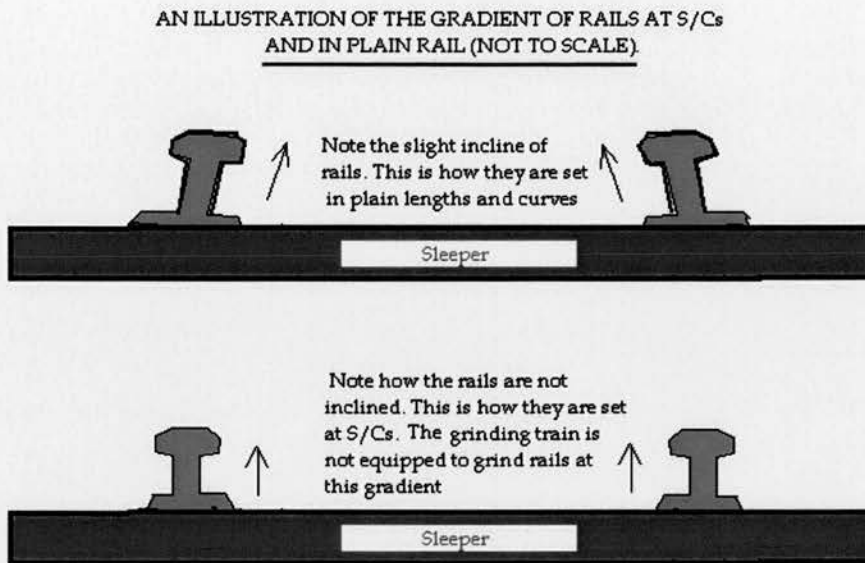


Figure 8-2 Rail incline in plain line and at S&Cs where the rail type is known as 113 lb/yd (author's sketch).

8.2 PRINCIPLES OF A NEW ACTIVITY

8.2.1 The core objectives when grinding a rail

Manually grinding the rail at S&Cs is a relatively new activity on the British network. Towards the end of 2000, post-Hatfield, it was decided that a rail-grinding programme should be implemented (Clementson, 2002a: Conference paper). Regular rail-grinding of S&Cs complements the train-based system, which was also re-introduced post-Hatfield.

To fully appreciate and understand the work of the men who rail-grind rail, some basic information about grinding procedures must be given.

When the rail head wears and deforms, metal movement can cause "lipping" (see glossary): a sliver of metal becomes detached and creates a jagged crust on either the gauge face or field face. Figure 8.3 illustrates (clockwise) the growth pattern of lipping.

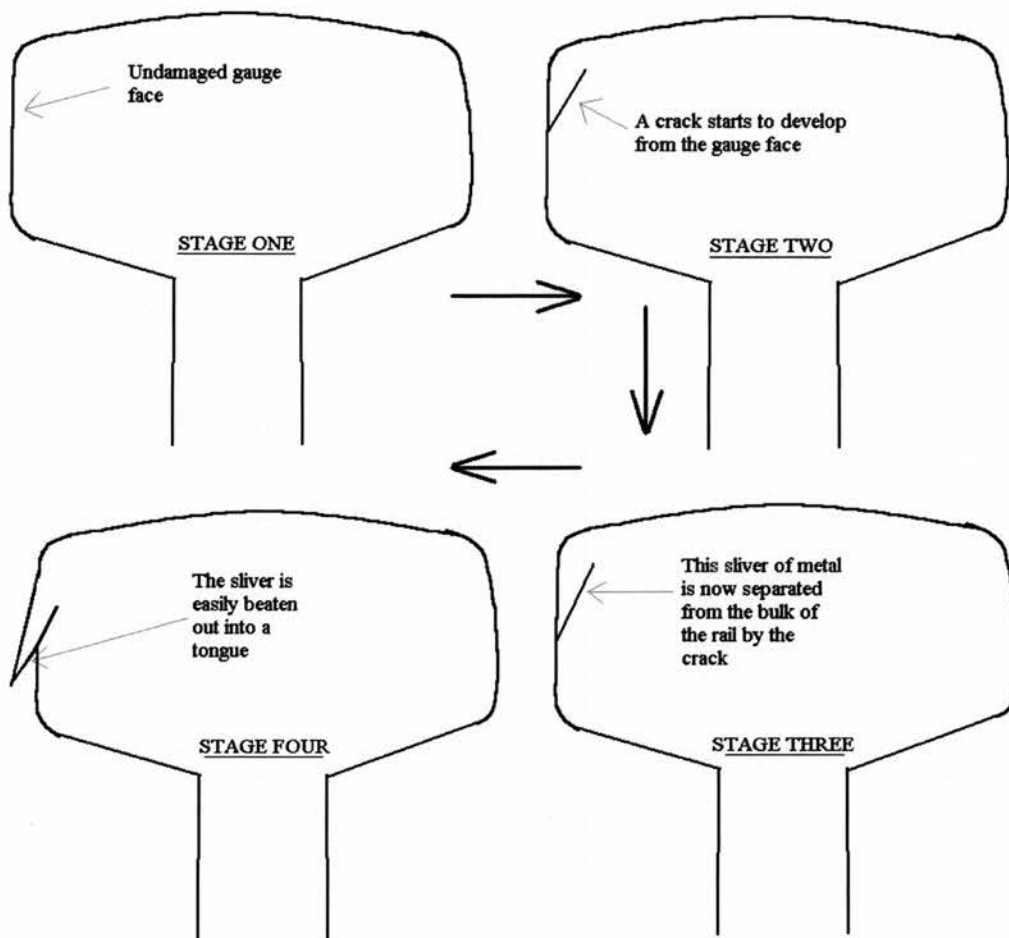


Figure 8-3 The development of lipping (author's sketch).

Removing the lipping is typically the first thing that is done by a manual rail-grinding team, prior to checking for cracking using a process called magnetic particle inspection. Then the rail-profile is assessed by placing a template over the rail. If the rail-profile is in optimum condition the template will fit over the rail head snugly (see fig. 8-4). If not snug, the rail head is uneven. The task of the team is to redress the profile⁷⁵. If shallow cracking is present, the team must also ensure it is removed as part of re-profiling whilst making sure not to grind too deeply:

⁷⁵ As an aside, instruction 14.2 of the latest PWSI4 tells us: Hand grinding of S&C should be undertaken to achieve the same profiles as those specified for plain line. The high rail "ATH" or "NR HR 1" profile should be used for the high rail or outer rail of all turnouts and a low rail "ATL" or "NR 113A" profile for either low rail or inner rail of turnouts and straight track (Network Rail, 2003: 14.2).

Standard hand grinding equipment can be used to grind out gauge corner cracks to a depth of up to 5mm (7mm in exceptional circumstances) (RT/PWG/002, 2001: 6-7).

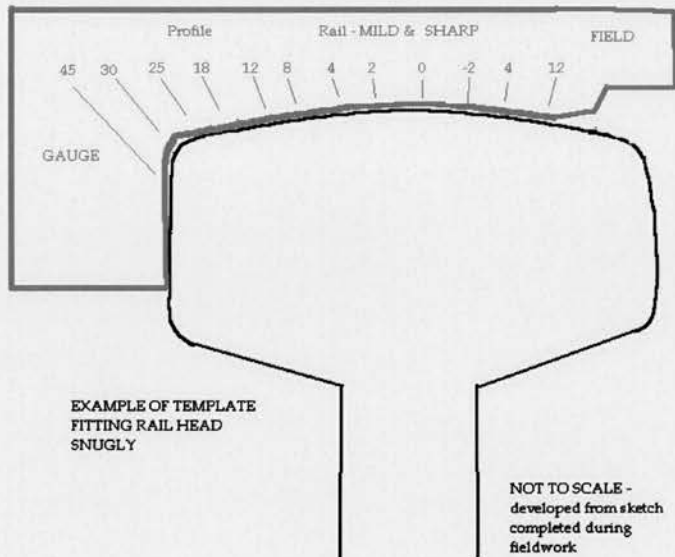
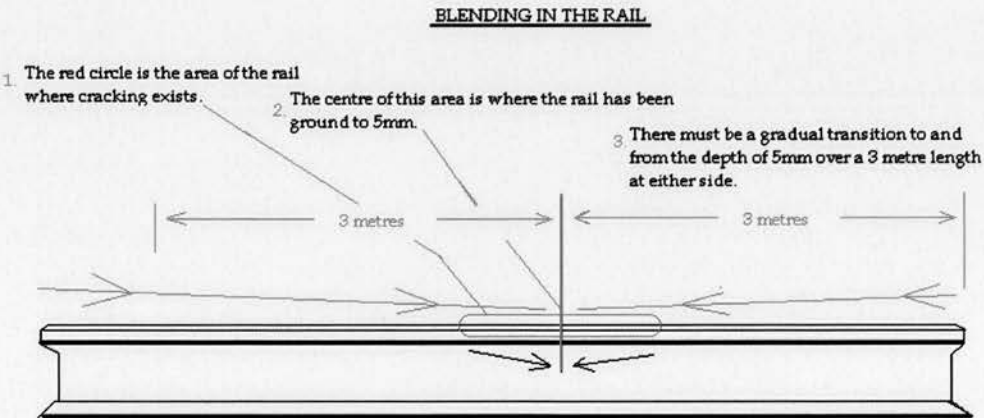


Figure 8-4 A snug fit between rail-head profile and template (author’s sketch).

When removing cracking and re-profiling, teams cannot grind the affected area of rail in isolation. This would create a dip in the rail making for imperfect ride- conditions (see fig: 8-5).



The grinding teams cannot simply attack the area of the rail affected with cracking alone. If they did, the grinding would create a "dip" in the rail's running surface as suggested by the short arrows

Such conditions create bad travelling conditions due to bad contact between wheel and rail.

This means, when grinding, the teams must "blend" in the rail to the surrounding rail.

For instance, if the rail has been ground to the maximum 5mm at one point, 3 metres of rail on either side of the 5mm point needs to be ground so as to allow a gradual descent and transition for the vehicle.

If the maximum depth ground is less than 5mm, the length for the transition grinding is less. The ratio for the rate of change is no greater than 1 in 600mm (RT/PWG/002:12).

Figure 8-5 Blending in the rail (author’s sketch).

Grinding involves repetitive passes over the rail with frame-mounted machinery. Each pass removes a fraction of a millimetre of metal from the rail surface until the shallow cracking has been removed completely (or until the maximum 5mm has been reached) and the desired profile has been attained.

8.3 THE PERSON AND THE MACHINE

8.3.1 Everyone's learning

The regular grinding programme for S&Cs is new. Its implementation came in light of the recommendations after the Hatfield derailment in 2000. What now interests us is how training for this "new" activity is organised:

The training is made up of a four day course, each day is eight hours, it's quite intensive. In the first day, in the morning they get the theory, then in the afternoon and for the next two days they're outside working with the machines. ... Then on the last day they're assessed. I ask them eight questions, verbally. They put the answers on a paper, and if they are bit vague I ask them additional questions, to try and clear things up, so I know what they're meaning, or trying to say. It's recorded as well. Then two years later I go out on to the site, assess them again, there's no point in bringing them all back here (Int: 28).

However, I was told that training was:

Shite... we were shown what we had to achieve... but not how you got there... that's all learned on site. There're different problems and they all have different methods for grinding the problem... even now..... we've been doing this for.... two years. We were one of the first to start grinding [here]... and still now... we're coming across new problems and trying to figure out how to get round them... There are so many different methods and variations (Fw: 15).

Because of this we can surmise that there may have been teething problems in trying to teach the course during the early days:

When it first started there were four grinders and [we] just had to "*teach it*", but we all had to learn our trade. ... When I first came into this job they handed me that file [the respondent drops a thick large folder on his desk] ... "*teach this!*"... It was death by overhead! There were things in there about ultrasonics that the guys don't need to know. ... But because there was no real experience in grinding S&Cs like this, I was learning about it at the same time (Int: 28).

Though the men were starting afresh, it was clear early on that grinding operatives had to have experience with grinding machines:

It's a difficult course to teach, it can be difficult to grasp – "*moving the running band?*" – So we need guys who have a history in grinding – they need to know how to make shapes. Whether they've come from within the industry or not – some guys have come from the shipyards... wherever [they have come from], they need to have had a history of using hand grinding machines. These guys with us, they were all welders, so they already knew the principles of grinding, new about the touch you need – that history is important. It would be very, very difficult, to teach someone who has had no experience, these machines are dangerous, so they've got to be comfortable with them, and confident (Int: 28).

This point was echoed by others elsewhere:

Grinders are generally welders because people naturally grind after welding. ... They [new recruits] don't come from pencil-pushing to grinding, they've had an engineering background (Int: 09).

And:

In [location] they've not got the men to do this work... They lost teams; their quality of work... was not the best... I don't mean to be derogative ...they weren't cowboys, but you can't take Joe Bloggs off the street whose got experience in electrics and ask him to grind a rail, he may be doesn't understand metal... or the process, so he'll never get a good result... There were problems... they were not getting right down to the rail, they were leaning too heavy on it and bang!: there's a gouge taken out the rail... There's a problem. There's a totally different quality [of grinding] across the nation... In Scotland the shipbuilding's in decline, [those] welders [are] men who've got experience with metal [and came to the railway industry]. They were getting a lot of praise, but the [rail] surface... it was too good, they were buffing it... a perfect sheen across it... doesn't need to be that good, you need a general profile and a rough surface is ok (Int: 29).

Getting to know the machinery, and finding out what it can do is thus, a key part of learning:

A new starter would take about six months to a year to get to know what they're doing... a new start wouldn't be able to just come along and push this grinder up and down the rail... it would keep cutting out on them for starters (Fw: 15).

Likewise, another passed comment on the skills needed for handling the machines:

When we first start teaching the guys, we tell them the shape we want them to get, and just let them have an attempt, and they'll make a complete mess of it (Int: 28).

8.3.2 Creating conditions

The men, when they first try to *grind a shape* practice at a complex specially set-up for rail-grinding, but:

It is difficult to simulate the conditions of real life here [at the training centre], because what the guys train on, there's no RCF. But what we do is we give them an HGI form⁷⁶, on that it says what is wrong with the rail, so from that they know the depth to grind to. It's as if there is RCF on the rail then, so then we assess them that way (Int: 28).

At the same training centre I am shown where the men use the machines for the first time. It is in a yard outside and there is a large layout of track:

This is a mock-up of an S&C; we give the guys a scenario, and they practice here. It's how they learn... The rails have been ground in areas, up and down the lengths, and when the rail is done, we transpose it so they can start on the other side. We don't just change the rails around ourselves, we use that as a learning process for trackmen, then again, when the rails need to be totally renewed, we have guys learning to be a trackman doing that. So it's quite good, this whole set-up gives a lot of opportunities for training, for trackmen and grinders. We've also got the facilities for a switchblade repair course and how to grind that (Int: 28).

Yet, the learning process is not just for newcomers to manual rail-grinding, those who teach, are also learning continuously:

We play with it [with the grinding machines] to see what it was that we could do.... Initially there was a lot of contact, but now with us having our own [technical] heads, we just make phone-calls to each other... We have a contract in [location]...and I'll hear that they're trying something new, or they'll hear we're doing something different... and they'll phone us and ask us what we're finding and what the limitations are (Int: 28).

⁷⁶ An HGI form – issued to a grinding supervisory manager (GSM) - gives location and type of problem and once worked, the GSM completes the rest of the form - saying work is complete or highlights any problems.

And of the re-certification of hand-grinders (two years after their initial course), it was interesting to note what one instructor said:

Then two years later I go out on to the site, assess them again. There's no point in bringing them all back here. I see what they've learnt in that time too though... if they've got new ideas (Int: 28).

Still, once training is complete:

When we put out new guys they always go with someone with experience, it's a must (Int: 28).

Basic training forms the foundations upon which grinding operatives build numerous skills. In the following section graphic accounts of my observations and experiences with teams of manual rail-grinders are given, this is done to demonstrate extensively how these skills are developed and utilised. The notes are taken from several different nights and are connected to give a systematic account of the working life of a rail-grinder and his team.

8.4 WAITING TO RAIL-GRIND

8.4.1 Organising rail-grinding: the job bank and opinions

I meet up with a Grinding Supervisory Manager (GSM) at 12:30am: a possession is planned from 1 a.m. to 4:30 a.m. There are two sets of S&Cs in close proximity to each other that require attention.

I sit with the GSM (Ally) in his van by the track. There are numerous forms, books, and folders in the van. He takes a large folder, opens it and removes an equally large pad of paper, unfolds it and tells me: "*This is the job bank for this area. All the jobs are passed on to us*". There are lists and lists of S&C grinding jobs for the area that Ally and his teams work. Looking at the headings on the job bank I see there are columns for: location of job; fault-type; fault severity, and I notice every single job is at an S&C: S&Cs are the only places they hand grind. They don't hand grind on conventional long stretches of line. "*It's cheaper to renew the rail in those places*," he tells me.

Ally also mentions how there could be sites within sites with different numbers. He tells me the same story I've heard before, but adds: "*something to do with the databases the faults are reported into*". Also when it's reported and the grinders are given the location, they are only given the S&C's reference, they are not told whether it is the blade or stock rail. Again, he mentions how this has got something to do with problems when transferring databases from UT reports to gauge corner cracking reports: I've "*highlighted this problem*", Ally tells me, with a hint of resignation in his voice (Fw: 03).

8.4.2 Who's who at a possession and how a new face can fit in

When I was at that possession (Fw: 03), I found determining "who worked for who" confusing. Ally was the GSM for a maintenance company; the six guys he was supervising are all agency guys, with whom he had worked for 18 months. The Person in Charge of Possession (PICOP) did not work for the same company as Ally; he worked for a smaller contractor who had booked the possession. There was someone called the Engineering Supervisor (ES) and the Controller of Site Safety (COSS) he is an agency worker as well. I noticed however, that there seemed to be some semblance of a hierarchy: work could start only once the PICOP had told the ES, who in turn told Ally, who then told his team it can start.

I found it interesting that Ally had to tell the PICOP what he and his team were there for. I had presumed that when a possession was booked, everyone working in the allotted period of time and space would know who was going to be there and why. I have found out this is not the case. Workers from many different companies can turn up and ask the PICOP if they can get into the possession.

I found out why this is the case. Ally showed me a book about one inch thick, like a diary; a page put by for one date and under which was a list of all the possessions all over the country that have been booked by different companies. Other companies refer to this book and send men out to do the work they want done. When these men turn up at the possession, it is up to them to basically ask the PICOP if they can get on the line. This book is renewed weekly but the possession times tend to be the same each week, thus companies and workers tend to know when they can get on a specific part

of the network. It seems this is why different people can turn up and why there are often new faces⁷⁷. During other nights I saw how people can just *turn up* at a possession to see if they can work:

The COSS tells me this possession was booked for the grinding that these guys are about to do, however, two men appear, introduce themselves and ask "*can we nip on over there*" (they point to the nearby station) "*it's just a bit of gauging by the platform*". "*Aye, no bother*," the COSS replies, and takes their PTS numbers and they sign their names beside it, just as I did when I first arrived. "*They'll be in and out tonight, they won't be here long at all*," the COSS tells me (Fw: 04).

Another example:

It is very busy when I turn up at five minutes to one in the morning. Numerous vans and a few cars are here; there's plenty of activity. I meet up with the GSM and the three man team. I mention how busy it is and one of the team agrees. I ask them if they expected this many people: "*you can never tell, it's swings and roundabouts*". He tells me how this possession is actually for the grinders I am with, and all these people saw it booked and came along and "*chanced there luck to see if they can get on*". If he (the PICOP) doesn't recognise them "*they should not get on, they should have used their own gumption and got it booked for themselves*", he says with a bit of a laugh. "*Can't complain, we've done it plenty times on other people's possessions*" says one of the team (Fw: 06).

8.4.3 Waiting to work – a problem

A task of the PICOP is to organise work around operational problems like late trains which can delay the start time. On one night it is not a late train that is the problem:

Ally has been talking to the PICOP. There is a problem that apparently, Ally says, occurs "*time and time again*". At the S&C, where a team will be working, (where a

⁷⁷ This had a profound effect for me as a researcher. I began to feel just like another "someone" and that I did not "stick out" as a new face as much as I had expected. Though the scene was intrinsically foreign to me, its structural make-up did not make me feel out of place at all.

branch line joins a main line) the switch is set so vehicles passing over it must be travelling on the main line and may not come from the branch line. The branch line is closed (see fig. 8-6), but the grinding team have to grind the gauge corner of the main line's stock rail. This means that shifting the switch blade "opens" the branch line (see fig. 8-6 left hand side), and the PICOP says the details of this possession does not allow for that route to be "open". Phone calls have to be made to the signaller and permission has to be sought for this process. After a short period of time and after clearance from the PICOP, work proceeds.

The interaction between the men during this episode is interesting as it seemed their different "occupational needs" generated the potential for conflict. Ally tells me that *"the PICOP was being pedantic"*, the work could have been done without the phone calls and the clearance, but the PICOP was *"going by the book"*, and *"he has every right to do so"*. After all, it is *"new faces all the time, he'd never seen that PICOP before"*, and the PICOP was *"only doing his job"*. Ally continued to talk about the current climate in terms of personnel and the communication between them: *"Man management is everything now, there're other guys who would have been like - what do you mean we can't have possession of that line! - Caused a fuss with attitude and got nowhere."* But he hinted as to why people get worked up about these things when he said: *"Still, you daren't lose time, the possessions are that short"* (Fw: 03).

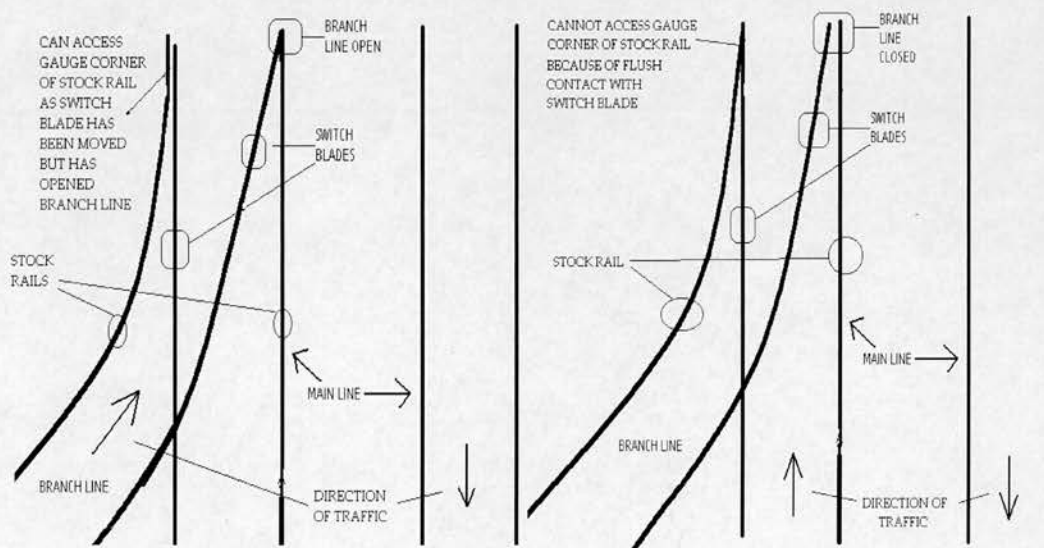


Figure 8-6 Illustration of a closed and open S&C, respectively (author's sketch).

8.4.4 At the start of a possession

The start of a possession is marked by the moving of bulky equipment from the back of vans to the relevant S&C which can be as much as 100 yards away. The men lift machinery onto the nearest track and push it towards the S&C. The others each grab an end of another grinding machine and balance it on one rail; then one of the men follows the first. The last of the team grabs spray paint; a spray on dye; and gets the very heavy generator ready to lift at the edge of the van when one of the men return. Eventually the men are parallel to the appropriate S&C: the generator is firstly put in place in order to power the portable floodlights that are set-up. Then the men, in twos, carry the de-lipper and the rail-grinder over the rails to the S&C where they will work

Getting machinery to the site and assembling it, all has to be done once the possession time has started. This means the actual grinding work starts some 30 minutes after preparation. When the men are ready to work, problems can still present themselves:

8.4.5 A hold-up – another problem

It's been a night of start and stops; there were problems at first with the generators, one was broken and, after getting another to the site, it ran out of petrol immediately. Then track patrollers appeared in their rail-compatible Land Rover. Letting them through was not a straightforward procedure. You can't just stand back and let them pass. A signaller has to be informed who has to ensure there is no traffic where the patrollers want to go. Then the signaller has to change the switch blades for the track patrollers after we make sure the rail is clear of machinery. Then the signaller has to shift the blades back to the original position, but only after knowing that the patrollers are gone – then before we go back onto the track we have to wait for clearance from the PICOP. We have been here for nearly 90 minutes, and only the lipping has been removed (Fw: 15).

8.5 THE DE-LIPPER

8.5.1 Removing the lipping

When the men get down to work the first thing they do is mark the length of the rail to be ground. Spray-paint acts as a border at each end of a length of rail. Then:

The rail is measured; you see what the wear is. The guys scope it together, they all need to know what is going to be done; what needs to be done; and they need to know what they're going to achieve at the end of the shift. That's when you need experience, the experienced guy will look at the work, and think, and know: *there's no chance of getting that length done in six hours*, so they split the work, and plan it over the nights. That's why they scope it...so they know that, *that'll take 3 hours*, that, *that'll take one night*. Then all the lipping is removed if any... (Int: 28).

A team member gave me a little more insight into "scoping":

... depending on the length of the S&C being ground, the time taken to grind it varies, but ideally an S&C takes four nights, and ideally it is a night for each rail, the stock rail, the switch blade, the other stock rail and the other switch blade [see fig. 8-6 for layout of stock rails and switch blades] (Fw: 04).

This plan could be spoiled:

...it depends on the length of the S&C and cracking – you can spend all night trying to get the running band and get nowhere – you have to go back to it the following night (Fw: 04).

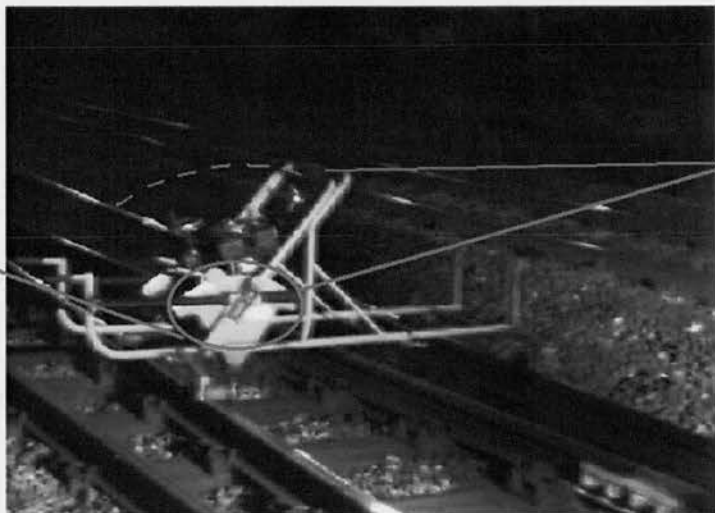
8.5.2 Operating the de-lipper

The machine that removes the lipping is operated by one person, it is a large machine that sits on both rails and is pushed and pulled along the railway track. The de-lipper⁷⁸ has a large circular grinding stone that sits perpendicular to the gauge face of the rail, and by levering a large handle the operator is able to place the spinning stone against the rail. By fluctuating between pushing and pulling on the handle he applies differing pressures on the rail with the stone. The harder he pushes against the rail, the more the metal will be removed from it (see fig. 8-8. "Knowing how" to apply pressure, however, requires tacit knowledge. The following set of field notes attempt to show how the operator of the de-lipper works:

⁷⁸ The proper name of the de-lipper is: the Frog and Switch (Int:28).

THE DE-LIPPER

Though hidden from view, there is a grinding stone that can be pushed against the gauge corner of the left hand side rail.



The area of the de-lipper in the circle shows the angle at which the grinding stone can be placed against the rail. The dotted line shows the direction of the handle that the operator uses as he exerts more or less pressure on the rail with the stone.

Figure 8-7 The de-lipper (author's photograph).

I notice that there is not a precise setting for "pressure". It seems to be free moving and entirely down to the operator's discretion: the angle of attack and the pressure applied is down to the operator's judgement *"Touch and feel is important"*, said a team member (Fw: 15).

Note how the operator is holding the handle that applies the pressure to the rail with his right hand. There is no precise setting to which he has placed the handle, it is all down to the pressure he "feels" he should apply.



Figure 8-8 Operating the de-lipper (author's photograph).

Periodically, the operator stops to ascertain his progress. On hands and knees, he checks the rail – he is figuring out how much pressure should be applied next, and where (Fw: 15).

To mark the progress of his work, the de-lipper operator has to pause his work, switch off the machine, and examine the gauge face and corner with his eyes.

No machines, no tools, no measuring devices of any sort are used here. He simply looks at the rail to form an idea as to how much pressure should be applied and where. when he next operates the machine.



Figure 8-9 Assessing progress (author's photograph).

Notice how the de-lipper operator has his eye on the area of rail where the grinding stone is. This allows him to chart his progress and adjust pressure as and when required..



Figure 8-10 Operating the de-lipper and the role of judgement (author's photograph).

8.6 MAGNETIC PARTICLE INSPECTION

8.6.1 An account of an awkward test

The lipping should be ground off and the rail examined carefully using magnetic particle inspection to check for the presence of horizontal cracking on the gauge corner and face, which may have formed and been hidden by the presence of the lipping (Network Rail, 2003: 14.19).

This is how a magnetic particle inspection is typically done: the rail that has been de-lipped is sprayed with white paint. Then black dye is sprayed onto the rail, covering approximately twelve inches at a time. Then they place the MPI device on the rail, and by pressing a button a slight charge is forced through the rail between the two probes at either end of the device. Any cracks within the space between the probes will show up as dark black on the background of white paint.

The men let me MPI a rail. It could be a one man job at a push, but I quickly see how it is better to swap roles for the tasks. It is an awkward job and considering it has to be done on two different rails over about 15 metres each, it isn't easy on the tester's back or knees – moreover, you're not just bent double between, and on, sleepers, but you have to manoeuvre yourself between the spars of metals and bars that come with the make-up of the S&C. I use the MPI device for a distance of nearly six metres. The device is not easy to use (Fw: 06).

The length of rail marked by white paint has just been ground by the de-lipper.

It is upon the white paint that a dye is sprayed for magnetic particle inspection.



Figure 8-11 White paint on the rail head marks out the area for MPI (author's photograph).

Operating the MPI device, in the abstract, sounds relatively simple and straight forward: the person holds the device in one hand; it is rectangular in shape, approximately ten inches long with two metal probes like pincers at either end. It is placed on the rail where the dye is, and by pressing the button the charge is released between the pincers, you can feel the device sticking to the rail and you can feel a sensation through your hand (if you are wearing a watch that keeps time by kinetic energy, the second hand will spin at a phenomenal rate⁷⁹). Even though designed to be held in one hand it is heavy and the handle is uncomfortable.

The device fits into your hand badly. The piece of plastic that is closest to the palm of the hand is too wide and too thick: it feels like a plastic brick, and trying to reach under it with your finger to press a small button to release the charge is extremely uncomfortable. I sometimes have to use both hands to operate it; this offers no respite from the awkwardness. It is a very uncomfortable job. To combat the poor ergonomics of the activity, we work in pairs. I'm in the 4-foot placing the magnet on the rail, one of the team is in the 6-foot spraying the rail, we go along together; spraying, testing, spraying, testing. One of the team asks me if I want a breather. I say I'll do another metre or so.

MAGNETIC PARTICLE INSPECTION

In the picture three team members are looking at the rail for small cracking. The man on the left has the tin of dye, he sprays it on the rail whilst the man in the centre is holding the awkward testing device, and pressing a button on the underside of it to send a charge through the rail between the two pincers and on the rail where I have marked two lines. The third man to the right is simply another pair of eyes looking for shallow cracking.



Figure 8-12 Looking for cracking during the MPI (author's photograph).

⁷⁹ MPI-ing is tedious, and on one occasion, whilst we were all staring at the rail for the umpteenth time looking for a crack, one of the men, somewhat sarcastically, said how time flies during this task. Only then to show me his watch and say: *see, told you so!*

Then I stand back and let the guys finish the job. They speak to me and to each other as they conduct the test.

In this picture the three members are discussing their work. Notice, however, how the rail has been coloured white. If any cracks are present the black dye would seep into them, and highlight them against the white background.

When a crack is found the team mark it clearly. In this instance they have circled a crack.

This way, when they start grinding, they can easily see where the grinding stone is attacking it. Also, they will also find it easier when they next come to test it with the MPI.



Figure 8-13 Discussing their work (author's photograph).

They tell me what they watch out for; if a crack shows up "*it is very dark*" (I don't see a crack during my time here), but twice over the length they stop and have a close look at the rail towards the gauge corner. "*Cracks are like that*" one of the team tells me... I see what looks to be a small series of cracks barely 4-5mm long, and indeed they have shown up to be dark once the spray has gone over them and the MPI has been used. But, they're only minor surface abrasions that you get from the MLC, (a type of grinding stone that is very coarse). I hear one of the men telling the youngest of the three who has been with them for six months, "*to slow down, and to let the spray drip right in ... to leave it for a few seconds... just to make sure*" (Fw: 06).

8.7 SHAPING PROFILE AND GRINDING OUT CRACKS

8.7.1 The profile

The men now know if any cracking needs to be removed whilst grinding for the profile. Then:

...the template is chosen, either for straight line, mild or sharp curve and whether it's the high leg or low leg [see "cant" in glossary]... Then the grinding is done... you can't just go at it, have to take it easy, it's a gradual process. If you went at the rail you would just flatten it, it's got to

be done gently or there's blue-ing, the rail head gets hot and will go brittle. When you've ground one rail, you have to grind the other, grinding one rail is only doing half the job: because you're shifting the running band it's going to affect how the train travels, so it's going to affect the other rail and the running band there (Int: 28).

The men place a template over the rail in the middle of the length to be ground and they shine a light at the contact line between rail and template and look to the other side for channels of light coming between the two. You search for channels of light by getting right down to the level of the rail and placing your cheek on the rail and staring into the join of template and rail.

If there is light coming through, the rail is uneven; it is too high in parts and must be ground lower. The template is marked into divisions, -4, -2, 0, 2, 4, 6,... to 18 – (recall fig. 8-4, page 230). Where the level of the rail is too high, a team member with a marker pen scores on the rail, perpendicular to the template, a shaded area. If there is more than one area needing to be ground, more than one shaded area is scored onto the rail. These shaded areas show the grinders the area of the rail that needs to be worked. However, it is not just a case of grinding the high-spots, gung-ho.

The team assess the profile of the rail with the template. They look for light from the torches between the template and the rail. Any light suggests an imperfect profile



Figure 8-14 Assessing the rail's profile (author's photograph).

8.7.2 Teamwork

They check the profile with the template and assess among themselves the area that should be attacked. I ask about this process: *"there're different methods for grinding each rail problem... sometimes it's not a straightforward case of grinding the highest spot, maybe you have to work the corner first and then work over to the high spot...., it all depends on the type of problem... the initial problem tells you how to grind...."*

(Fw: 15)

Then:

Sparks are flying as the grinding has started (Fw: 03).

The operator of the machine pulls and pushes it along the length of rail, turning a handle like a steering wheel in a car. This allows the grinding stone to move over the surface of the rail head – from gauge corner to field corner. Another function applies the stone to the rail with differing pressure.

Grinding a rail is a long process. It is not a case of fitting the machine to the rail, in-putting dimensions and running it over the rail to gain the desired result. Instead it is a stop and start affair that needs to be monitored continually, and which relies on the tacit knowledge of the operators.

The hand-grinder: note the steering wheel that the operator uses to turn the the grinding stones over the surface of the rail. Also note how there are no pre-set precise settings. Again, operating the machine requires judgement, touch, and feel.



Figure 8-15 The manually operated hand-grinder (author's photograph).

It is a stop / start affair because:

Each skim of the grinder over the rail removes just a fraction of a millimetre of metal, (the maximum they can remove is 5mm).... you can go harder (with the grinding stone) but it shifts the high spots (Fw: 05).

After so many runs along the rail the operator stops and places the template over the rail head to assess progress. This stage is not reached quickly. It takes time.

One of the team told me that there are "*high spots and low spots on the rail, if you grind too far then your higher at the other side, it takes a lot of feel...a lot of moving and adjusting, takes a lot of judgement... and we don't have much time, we'll be lucky if we get it done tonight*".

One of the team
assesses the
profile himself



Figure 8-16 Assessing progress (author's photograph).

After a cycle of runs the team members have a close look at the template.... I listen in to their conversation during one of these moments. During a lot of pointing, looking, and touching, I hear them say things like: "*There.... one skim, check it*".... "*It's too square here, feel it here; it's rounded: needs to be like that* (he instructs with his hands), *try just taking a skim of it*". It seems to take a lot of time and I would say patience also.... At one point, when the team had been grinding the length of rail for

over 45 minutes, one of the team looked at the light flooding through under the template and said "*no even fucking close!*"

And this is how it went for the three hours we were there; grinding, check the profile, adjust the stones, grind, check the profile, adjust the stones.... and so on and so on... (Fw: 04).

8.8 BEYOND WORDS: THE ROLE OF TACIT KNOWLEDGE

8.8.1 Communication and foresight

After spending some time with the rail-grinding teams, I suggest to them that they appear to *need-to-know* what the rail will look like *after* some passes with the grinder: one pass with the grinding machine is only one small part in an otherwise long process, and each pass surely impacts on the next whilst the objective is chased:

"Aye, you need some... idea, some foresight... you've got to know how grinding one area of the rail will affect the rest of the rail," ... It takes discussion? I asked. "That's important... everyone's got to know where we are [during the grinding] because you swap over, its not the same person grinding the rail all night, we swap over, so we all need to know where we grinding... it's because we all take turns⁸⁰." (Fw: 15).

Therefore, communication is a critical mechanism in this working-system if grinding is to be completed successfully. However, it can be quite noisy at times – grinding the rail is loud, and this can be multiplied if there is another team working nearby.

Therefore workers tend to wear ear protectors – and because of the dust that is kicked up during the work, protective face masks are usually worn which cover the mouths of the men. But communication is required, thus hand signalling between the men is important.

I noticed one man checks the gauge face whilst the operator, some yards away, stands with the machine and waits for "instructions". But because of the noise and the

⁸⁰ "You must rotate the operators ... they're heavy machines" (Int: 09).

equipment the men are wearing, the man checking the profile communicates with the palm of the hand and with fingers pointing straight and by moving his hand to an angle. This way he "shows" the operator the angle that he should next attack the rail. With a nod, the operator shows he has understood (Fw: 13).

Even when close together, the men "discuss" non-verbally where the rail should be ground. They often remove their gloves to touch, feel, and caress the rail. They feel for ridges that can be imperceptible when looking from above and can be equally difficult to notice when lying flat down by the rail, so the best indicator is "feel". But the entire team needs to know where the ridge(s) / is (are) – because they grind in turns.

They all take turns in feeling the rail at different points: then it's a nod of approval here, and a flat palm of the hand skimmed over there, and a finger tip touched here, and then some eye contact with each other, then more hand signalling around the profile of the rail (Fw: 13).

I realise that the hand-movements imitate the direction of the grinding stone – the operator copies the hand-movements when next operating the machine:

Whilst looking at the rail with the template they demonstrated with their hands the motion and the direction that the grinder should take as it passes over the rail. The grinding operator then duplicated with the machine the same "movement of the hands" during the discussion. Again, after so many grinding passes the process was repeated with the template and again a discussion took place between the three and the terms the men spoke in were simple, "*you need to hit this bit, move it up and down – like this*". To me, the words seem quite nebulous, and that more is "said" with hands movements.

When the template was on the rail I was given the chance to look at the light passing between the rail and profile. I saw "the desired profile" and the "shaping of the rail" that had to be done. I could see how it was simpler to see, and feel, *and then express with your hands* how the machine should be operated and manoeuvred over the rail head if the perfect, flush, profile was to be achieved (Fw: 03).

A team member stops grinding and assesses his work and the profile of the rail.



Figure 8-17 Grinding operator assessing his own work (author's photograph).

Shaping the rail often requires the running band to be shifted (recall fig. 8-1, page 226). This is because the running band can often “move” to an incorrect position:

"You see... the track, the rails, shift and move and the contact point of the wheel and rail moves, so we grind the rail to move the running band, back to where it should be⁸¹." He shines his torch on the rail, and says "look, here is where the wheels are running (offset to the left side of the rail, between the gauge corner and the centre of the rail; indeed I can see strip of worn metal about as wide as a small coin that runs along the rail), we need to grind the rail so we shift the running band to here" (bang in the middle of the rail, at the highest point of the curvature of the rail head) (Fw: 03).

"The profile isn't an exact gauge, it is only a guide... we try and get it flush, but if there is still a high spot in the middle of the rail we might be as well to leave it, as soon as a couple of trains pass over it with a weight of a few tonnes it'll flatten" (Fw: 05).

⁸¹ This connects with what the worker from chapter six, page 173, said about rails having an existing memory.

Despite these words, I found that the grinders (during my research period) tended to finish their shift with a snug fit between profile template and rail.

8.8.2 Don't let there be light

When the teams are progressing well there are long periods of grinding before they stop and check the rail profile. I am given the opportunity to see the profile for myself when they stop grinding. I see it gradually form into the desired shape. It is amazing just how little metal they remove; fractions of millimetres over the entire night.

This time, when they assess the profile, they ask for my opinion. I take my hat off and place my cheek on the rail and look very closely at the join of the template and rail... I think that it is just too high at the number 8, and I run my finger over the area and can feel a very slight ridge. The two men agree with me and mark a small area of the rail. After several skims they ask me to have the first look. I think that it is perfect; the template over the rail is snug. The GSM agrees, and is happy with their work thus the team start packing their equipment and head back to the vans (Fw: 14).

The photograph shows how the team have marked on the rail the area that is too high. Notice how they have written "8" referring to the template division. They have also scored a long length into the white paint, indicating where the ridge is. They have also drawn an arrow pointing at the ridge; demonstrating to the grinders where the highspot remains.



Figure 8-18 Marking out the high point (author's photograph).

8.8.3 It's all in the blend: imperceptible processes

Though the teams get the template to fit perfectly, they must also simultaneously blend the rail into the surrounding area so there is a slow transition to the deepest point of grinding. To blend it in there are two buttons on the grinding machine; one button raises the stone, the other lowers it.

The operator must use his judgement for, depending on how long the button is pressed, the further the stone will go down or up. Pressing the button like you would a light switch does not move the stone to a pre-programmed setting. Instead, the operator has to know how long to keep the button depressed, which depends on how deep the operator wants to grind. This begs the question: how does the operator *know* how long to keep it pressed? Tacit knowledge, once more, appears to be required, for the answer to my question captures virtually everything about grinding a rail:

"You just know, you get to know, it's all about feel". He then tells me that sometimes *"you can [physically] lift the grinder – that blends it in"*.

I watch the men grinding the rail; I see how randomly they press the button to lower or raise the stone: *"They push the button as when they think"*, says, Ally, who then raises the same point that one of the men just told me: sometimes they might *"just lift the grinding stone ever so slightly as they come to the end of a run"*. I watch out for this, and when one of the men has finished his grinding turn and lets another have a go, I ask him if he raised the grinder manually, without the button. He says *"yes"*. It was a process that was imperceptible to me (Fw: 14).

After watching closely (but failing to notice) whether the men lifted the machinery to blend in, I am told:

"You just have to know when to lift it... to blend in the rail... you have to know when to take the pressure to blend in"(Fw: 15).

8.9 TACIT KNOWLEDGE TACTICS

8.9.1 Different strokes, opinions, examples, and problems

Shifting the running band and profiling is a difficult, time-consuming, repetitive task which relies on tacit skills. These tacit skills are directed, shaped and utilised by judgement and interpretation which are at the discretion of the group and the individuals. Because of this, we may ask whether there are different grinding tactics among groups.

They have checked the template and have started to grind, positioning the stone as and where they think. I noticed that this team, as opposed to the other team, do not

have a marker pen to mark on the rail where it should be ground: a scratch with a stone from the ballast on the rail is enough for them. I notice also that sometimes, when it is just one person that has checked the profile that he too doesn't always mark the rail, he just "automatically" places the stone where he "knows" it should be. ...After a few passages they stop and check the profile again. It is very close to being finished. They discuss the next step in these words: "*Just two high spots... one pass here and one pass here*"... though there is some verbal discussion, a lot of communication is by hand signals and gesticulation and by means of touching the rail and pointing at specific parts of the rail head.... But again, there is no mark put on the rail, the stone is just guided to the area of the rail that needs to be attacked (Fw: 15).

Accordingly, I was told elsewhere:

Different teams, different guys have there own way of doing it. This team tends to grind the rail right through in one sweep, whereas other teams might do a metre at a time, either way, they're bang on at the end of the day (Fw: 13).

And elsewhere, a GSM said:

They're good at doing this, they know how to do it: their method seems to work (Fw: 03).

The idea that teams grind in different ways was consolidated by another:

He told me that when manual rail-grinding first started in Britain, a specialist from America visited. In America they have been doing this for years, but he saw how we were working, and said, "*see your profile, throw it over that wall. See, you're maybe removing all the cracking, but you're not working to how the trains are running, you're working to the gauge*". The worker explained to me that the American visitor was referring to the design of the cant, and how it is only ideal for one speed. Yet there are different speeds for different traffic on the curve and we continually re-profile the rail to one profile regardless of the cant. He told me that at times this process is not working: "*the running band will tell you where the trains are running so it's better to work from that than from the profile. We found that that works well. I mean, if we profile a rail one night, then we paint it and come back the next, we'll see where the running band is* [for there will be a clear running band worn into the painted rail by the passage of the traffic during the day], *then we grind it to the running band – and we've found that six months later it's still fine*" (Fw: 18).

During this conversation the same worker told me that there was some disagreement over this grinding strategy. He told me how others were convinced that they should:

"Work to the gauge, work to the gauge, they say, but I don't think it's as simple as that: maybe the gauge is telling you it's right – but the running band is telling you differently the next night, so it's wrong, the gauge should only act as a guide. I mean we're not a million miles away from what the gauge says the ideal profile is, but we've shifted it fractionally, and it can make all the difference". So, I asked: how do you know how to work away from the profile, and how to use the running band as a guide? – *"Now that's the difficult bit if you're to say how, it takes experience, after sometime, when you know your machine you can get it bang on. Sometimes you come back the next night and you see the running band running perfect, right down the rail like a laser beam – perfect! I'm not putting a feather in my own cap, but it's good to see, and.... to get that it's difficult, and it only comes when you've been doing this for some time"*(Fw: 18).

Getting to *know your machine* was discussed by another:

The guys have all told me that they prefer the MP12 over the De-burrer⁸², even though the way they have to operate it they'll get a sore back, but it's because they get feedback from the machine, the operator needs feedback, and you don't get that with the de-burrer. When you're raising and lowering the stone you're only using two buttons and you can't feel the tightness of the stone on the rail, but with the MP12, you can, and with that you can get any profile you want (Int: 28).

8.9.2 Losing running bands and losing tempers

The social norms that underpin a grinding team's work are closely coordinated and complicated. Each member is relied on for the quality of the work: such a tight set-up based on delicate and subtle communication suggests that things have a real possibility of going wrong.

You need skilled men for this job, and you need men who care. We lost a guy, he was useless, he wasn't interested. When the COSS was speaking to us, he was away wandering not listening,

⁸² The MP12 and the De-burrer are two types of grinding machines.

but when he was working, he was maybe removing a fault, but he was grinding in two others (Fw: 18).

During all my time observing rail grinding, I never saw such characters: each team member, to my eye, seemed committed to the cause. Despite the best efforts of a well functioning team who have successfully ground hundreds of S&Cs, things can still go wrong, and on one night of research I witnessed a problem. It was then that I saw that patience plays a part and that the progress of work affects the men individually in different ways.

The team are nearing the end of a possession. Things have not been going well. They have been struggling. They have been grinding one area of the rail, then another, and back and forth, repeatedly for the last hour or so. Gaining the desired profile of the rail is proving difficult. During a moment there is a verbal discussion: "*swipe it there*" and "*just three swipes there*", "*there's not much in it*".

But a member of the team seems to grind just a fraction too far after some passes causing high spots elsewhere on the rail that then in turn must be ground. After three hours on this rail the patience of one of the men is wearing thin and after grinding the rail and then watching one of his colleagues measuring the profile with the template, and then marking on the rail a sizeable area that still needs to be ground, he looks to the heavens in despair and walks off cursing, leaving the grinding machine without an operator. The man who marked the rail watches his team mate walk away, then he himself, walks in silence to the machine to take over. The operator that walked away is sitting on an embankment looking at the floodlit scene before him from a height – he has lit a cigarette. I go over and join him. I ask him the obvious question: "*Things not going well?*" The answer is littered with spluttering expletives which is not so much directed at me but at the rail which the grinder has kept a steely eye on. They are indeed having problems, "*We were closer to it at the start of the night, it's all this fanny-ing about, you should just place the gauge over it, mark it, grind it, and that should be it, but it's all this fucking about, grinding here, grinding there, grinding here... Pisses me right off!*"

One of the team ground just a fraction too far, and "lost it" (the running band, and his temper), I note fiery glances between the men, and I feel a bit of an atmosphere has

developed. At the moment I decide I will refrain from asking further questions about grinding a rail (Fw: 13).

8.10 SUMMARY

In the last example where one of the grinders ground “too far”, group solidarity was broken because of the “temporary” failure of the task: the problem was solved a little later. Those social mechanisms and social norms discussed through out this chapter, which manual rail-grinding teams develop and utilise to successfully grind appear, on the surface, to be routine and taken-for-granted. Instead, this episode, where the grinders encountered real difficulties, shows how complex the task is. The taken-for-granted routine that teams adopt to skilfully grind a rail, is on the contrary, far from straightforward. In this chapter and the two preceding it, I have analysed the constitution of such skills in terms of visual and UT inspection, and grinding, thus I have noted how these skills are developed, and utilised. Quite evidently much of the maintenance work detailed is a group process, meaning that the transmission and mutual understanding of these skills is an important, socially interactive part of effective rail maintenance. However, as many of the skills cannot be codified or formulated explicitly, I have drawn attention to the key role of tacit knowledge and mutual tacit understanding. Again I have shown how groups and individuals develop this special form of knowledge. Consequently, I have shown the problems created by paperwork such as following instructions and completing forms. In the next chapter, all these matters are again analysed, but in the context of Swiss Federal Railways.

9 MAINTENANCE AND RENEWAL ON THE SWISS RAILWAY NETWORK

On the factual level, evidence collected from other comparative groups – whether nations, organizations, counties, or hospital wards – is used to check out whether the initial evidence was correct. Is the fact a fact? ... Sociologists generally agree that replications are the best means for validating facts (Glaser & Strauss, 1967: 23).

9.1 INTRODUCING SCHWEIZERISCHE BUNDESBAHNEN (SBB)

9.1.1 Preamble

Until now, the entirety of this thesis has been about rail maintenance in parts of the British network. In this chapter we look elsewhere to see how another national industry completes rail maintenance. The Glaser and Strauss quote above refers to the values of a comparative study. As discussed in chapter two, the methodology I employed for my Swiss based research replicated the methodology I employed in Britain.

9.1.2 Swiss rail statistics, facts and reputation

Switzerland has a handful of small privately operated railways that operate in mountainous regions such as the Bernese Oberland. These systems generate the majority of their income from transferring tourists from valleys to peaks. It is, however, operating traffic over a network of nearly 3,000 kilometres that makes Schweizerische Bundesbahnen (SBB) Switzerland's biggest travel and transport company. SBB is the commonly used acronym when referring to the German name of the company that owns and operates traffic on the network. In multilingual Switzerland the same company may be referred to in French as CFF (Chemins de Fer Fédéraux Suisses), or in Italian as FFS (Ferrovie Federali Svizzere).

Swiss railways are commonly reputed to be a world leader in rail travel and technology. In January 2004, *Modern Railway* magazine published a three page spread analysing the Swiss system under the heading “Switzerland’s Amazing Railways”, whilst an article in *The Times*⁸³ was titled: “The man who makes the Swiss Railway run like clockwork explains”. Perhaps the highest accolade is found in *The Rough Guide to Switzerland* (2003).⁸⁴ The introductory paragraph to “Getting around” Switzerland assures any impending traveller or tourist:

The efficiency of the massively comprehensive Swiss public transport system remains one of the wonders of the modern world. It’s hard to overstate just how good it is: you can get anywhere you want quickly, easily and relatively cheaply; everybody relies on it as a matter of course; and it’s clean, safe and pleasant (2003: 29).

The Federal Swiss State has a vital role within the operation of SBB. SBB is, under special law, a limited (private) company, however, it is owned 100 percent by the Confederation. SBB often employ the services of private contracted parties to complete work; the role of the private contractor has become more significant in recent times due to organisational change. “A new administrative board has been created with greater decision-making powers, the railway is now a state-owned limited company and has been split into three separate businesses: passenger, freight, and infrastructure” (*International Railway Journal*, Dec. 1999). That was in 1999; in 2004 (during research) there were four businesses. The following is an illustration of the current make-up of SBB, with an in-depth look at how maintenance and renewal of the network is now organised.

⁸³ *The Times*: 02/10/03.

⁸⁴ *The Rough Guide to Switzerland* is one of a series of “Rough Guides” publications that cover many different countries. A volume is a “must have” for any traveller whose budget requires of them to be financially astute, as I was during the fieldwork for this thesis.

9.2 INFRASTRUCTURE

9.2.1 Organisational Structures and ideology

The structure of SBB is relatively simple to follow, this is perhaps because “layers of middle management [were] ruthlessly discarded in favour of a slimmer management structure which provides more direct communication between the board and the operational managers, and enables important decisions to be taken much more quickly” (International Railway Journal, Dec. 1999). SBB is headed by the “Verwaltungsrat” (board of directors) which consists of nine people. Under their control are SBB’s main businesses which are divided into four areas:

- Personenverkehr (Passenger Traffic);
- SBB cargo (Freight);
- Infrastruktur (Track and Track Access);
- Finanzen (Controlling / Real Estate).

Within each business there are sectors that deal with particular matters, see figure 9-1.

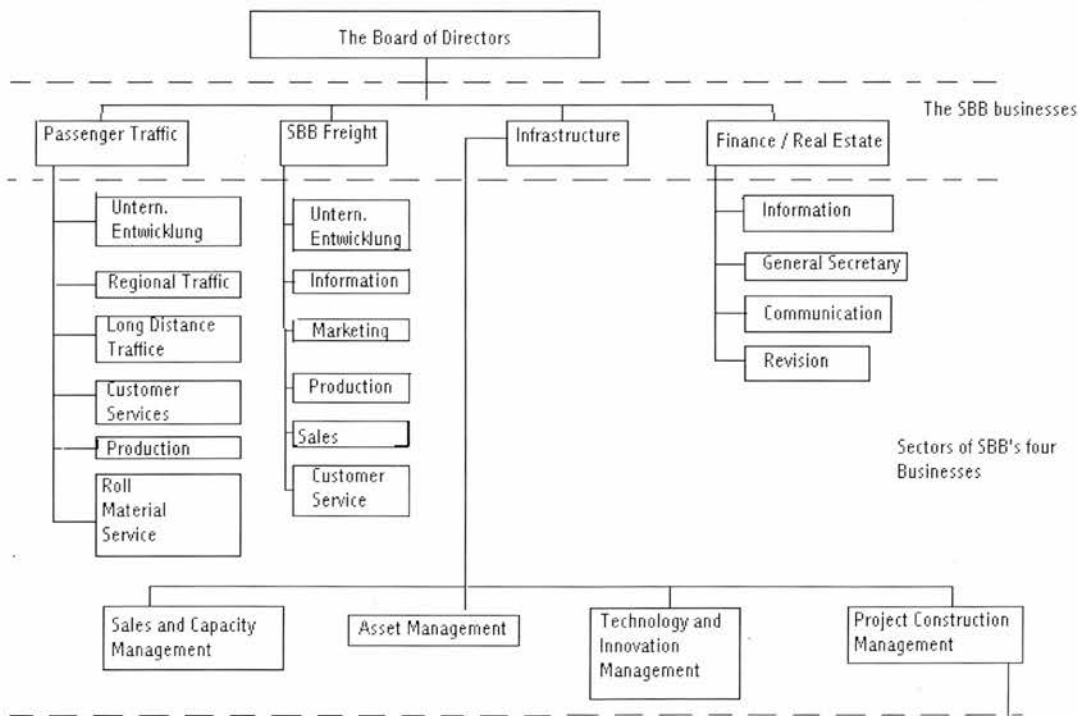


Figure 9-1 Business sectors of SBB (author’s sketch).

Our interest is Infrastruktur. The streamlined decision-making process that underpinned the restructuring of SBB as a whole is evident within this business. The words of the former Infrastructure Head, Pierre-Alain Urech, highlight this: “Our motto is simple: clear tasks and clear processes in the organisation. In the competitive environment that we agreed to create, there is no place for duplication”.⁸⁵ Within Infrastruktur, four sectors contribute to the operation of the business (fig. 9-2):

- Sales and capacity management (Verkauf & Kapazitätsmanagement);
- Asset management;
- Technology and Innovation management;
- Project construction management (Projekte Bau Management).

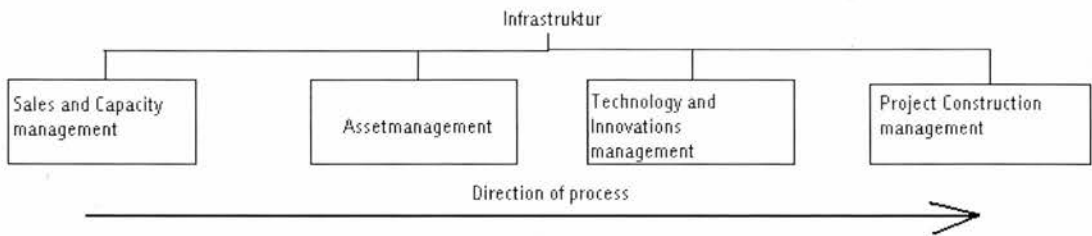


Figure 9-2 Work process in Infrastruktur (author’s sketch).

Our interest is focused on “Assetmanagement”. This sector has two divisions: Safety and Availability (VS), and Network Programme Management (NPM). The decision-making process involved with NPM is focused on financial control:

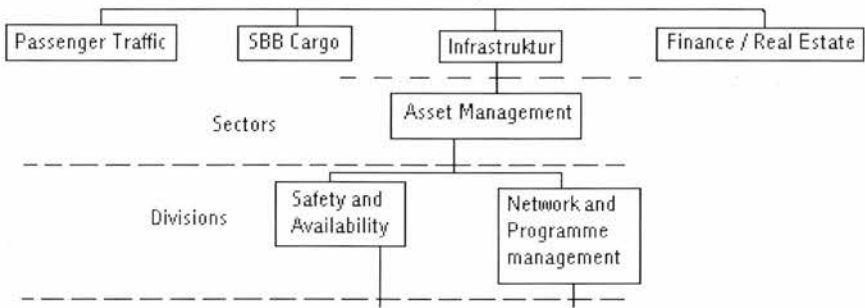


Figure 9-3 The two divisions of Asset Management (author’s sketch).

⁸⁵ This is my translation from French. The original quote is as follows: « Notre devise est simple: des tâches claires dans une organisation et des processus claires. L’environnement compétitif que nous entendons créer ne laisse aucune place aux doublons ». Taken from the SBB produced pamphlet « Nouvelle organisation Infrastructure CFF ».

9.3 FINANCIAL DECISION-MAKING

9.3.1 Models and the difference between maintenance and renewal

NPM leaders seek to answer two fundamental questions:

Our group [NPM] has two main questions. 1. How much money do we have to spend to maintain [and renew] our assets; that's the first one, how much money do we have for the track – very easy to ask, but very hard to answer. And then the second question. When we know how much money we have for the track we need to know how to spend this money. (Int: 31a & b).

For renewal work, money is spent largely on hiring private contractors. Despite this, SBB is still involved extensively with the work:

All machinery is owned by the contractors, it's always been like this. The strategy we use for the infrastructure is we engage people for track renewal work, and overhead work. The material for the work is put in place by SBB; transported to the site by SBB. We have a history of this. The decision of what needs to be done, and when it is done, is up to us. There is a specific organisation for coordinating the parts – getting the material to the location and planning who is doing it. So when we know what work needs to be done we can tell them – there is this work and when it is the best opportunity for the inceptions [possessions]. So we can tell these people with the machines – you come here then (Int: 30).

SBB only employ companies who are totally railway oriented. Civil engineering companies with, for instance, a “railway division” are not involved:

Interviewee: ...this department, they make the contracts, they execute the contracts for railway engineering contractors. We don't have a general civil engineering company; our contractors are typically railway engineering contractors.

Interviewer: So their interest is only in railway engineering, not just general engineering?

Interviewee: Yes (Int: 31a).

9.3.2 Splitting costs and Integrated Maintenance Management

The question regarding how to spend money has no simple answer. To aid the process, maintenance and renewal have been segregated. Maintenance is the concern of Availability and Safety (VS) ('A' in fig. 9-4), and renewal is handled by Project Construction Management ('B' in fig. 9-4), of the sector Project Construction.

It is split for finance – they (VS) do maintenance, and they (Project Construction Management PCM) carry out the renewals. They are the two groups. Before they used to be in the same group [in terms of financial management], but now it is different and it is this way [i.e. separated financial accounts], (Int: 31b).

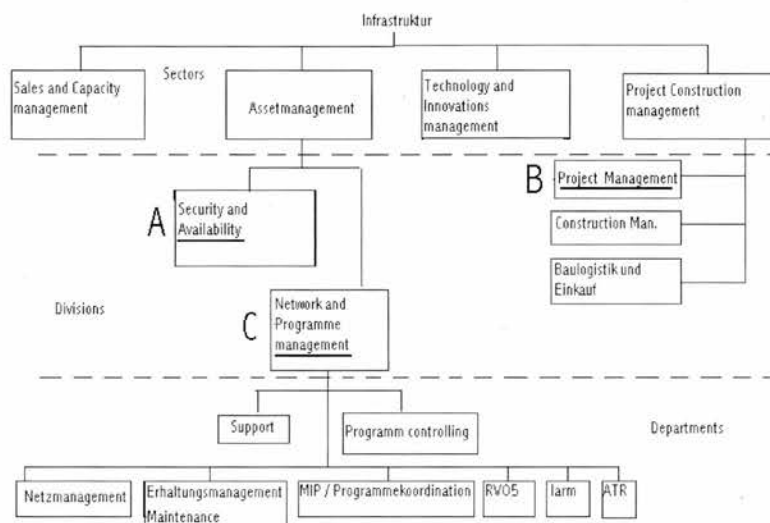


Figure 9-4 Splitting objectives and finances (author's sketch).

Separating the costs is not easy; drawing a clear line between what is renewal and what is maintenance is difficult, and NPM has the task of deciphering the two ('C' in fig. 9 - 4).

To say what the difference is between maintenance and renewal is difficult. It is given by financial calculations. With maintenance you are not adding to the substance, you are not increasing value, but with renewal you do. Renewal increases the worth of the network, its like paying up the mortgage on a property; this is why it is important to separate maintenance and renewal. And it is the task of NPM to manage this, they are the financial managers. ... Getting the balance between renewal rates and maintenance, however, is difficult – but this is the model we work with [during this conversation the respondent sketched a rough graph that depicted the *model*, I have re-done that graph below – see fig. 9-5] (Int: 34).

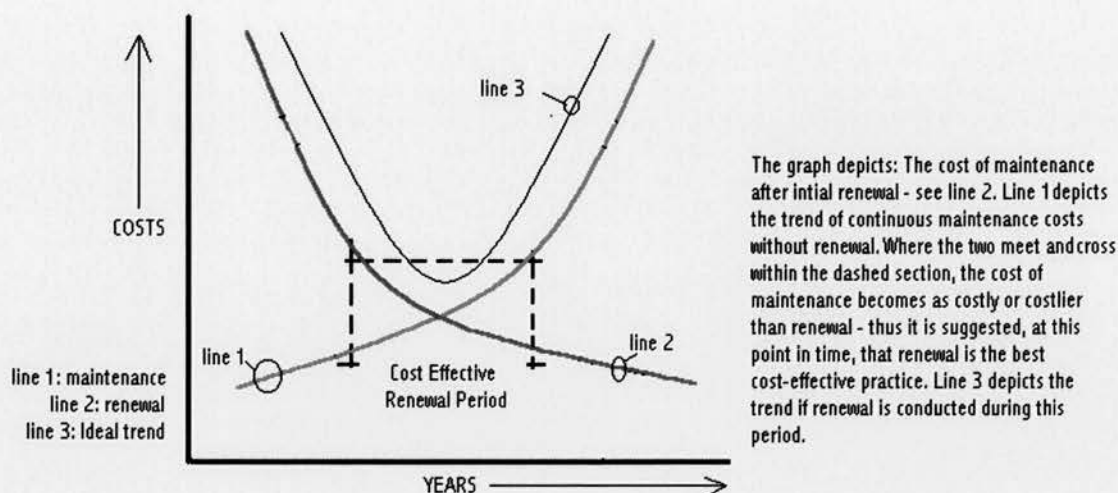


Figure 9-5 The maintenance and renewal model (author's sketch from Int: 34).

The decision-making model given above has been simplified. Deciding how to manage costs is best seen as the outcome of a tapestry of choices that spring from several different sources:

Do we give it to the person who is crying the loudest? [This is] the question we have to ask, so we are organised in the following way. ... We have one person who is making a simulation model to find out how much money we need. Then we have the programme managers, they are the guys who have to spend the money in the most intelligent ways. ... This team works with the other group of Asset Management VS ['A' in fig. 9-4] (Int: 31a).

Recent considerations for maintenance have resulted in the development of a new position: the Integrated Maintenance Manager. I refer to the words of an SBB member who talks about this recently fashioned position:

In our department a new position was created, we have a new colleague – just been here for two months – and he does work for what we call Integrated Maintenance Management. This came about because we found out that until now maintenance had always been the task for the Infrastruktur division, but involves also the influence of the traffic division. The influence of the traffic on the cost of the work is very big. You have limited durations of possessions and they have a very big influence on the costs. Say the length of a normal possession is 5 ½ hours: then for traffic reasons you have to reduce it by one hour. The cost of the work that needs to be done, but cannot be completed then increases by 20-30 percent, incredible. It's a very big influence. And so we say now, the people in the department that runs the trains, they have to take some responsibility for the maintenance. And that's what

we call Integrated Maintenance Management [IMM]. We are convinced there is a lot of money to be saved here (Int: 31a).

During one specific stint of research I was given an insight into the practicalities that the IMM must handle. Given the mountainous environment of Switzerland there are many, many tunnels, and given the length of some⁸⁶, I wanted to know if work within tunnels presented unique problems. This assumption was driven by an observation during fieldwork where renewal work was planned for a length of single-line track in an isolated location that was difficult to access:

Single line working

We arrive at the site – it is a single line. The single line is situated in a stunningly beautiful landscape. The length of track to be worked on is curved and situated on the side of a small hill. On one side of the track there is a slope that climbs steeply above us. On the other side there is a steep slope that falls sharply down some 12–15 feet. The track curls into sight from round the hill and then straightens up as it heads over a level crossing and onwards for about half a mile to the small station of the nearby village which itself is shadowed by the Alps. The back-drop to the track work tonight is thoroughly imposing.

On the track there are several workers with orange fluorescent jackets and hard hats. To get to where the men are we walk along a specially made path from the nearby station. We walk along the top of the embankment – on the side that drops 12-15 feet. The path was specially prepared – probably about a year ago. Franz tells me this work would have been planned five years ago – thus they knew that adequate access for walking would be needed – hence the reason the path looks very new and clean. The narrow path is just wide enough to stand on safely at the top of the embankment as a train goes by. The train that goes by is the last service to operate on the line – and it is the service that the workers have been waiting on before work can start.

⁸⁶ Such tunnels include the famous St. Gotthard Tunnel, which at 15kms long, will be dwarfed by The St. Gotthard Base Tunnel which is due to open in 2012 and will be a staggering 58kms long.

Once the train is in the nearby village station, the foreman uses a mobile phone to call a signalman who ensures that the line is now clear. Then the overhead power supply is killed. This is a must as some of the machines are quite high and could electrocute the men.

Here I saw the influence of traffic on work, thus I asked if it is a problem: controlling work for traffic or vice versa? Franz tells me: *"It is not a major problem – the people who control the traffic... they know the work must happen and they know when it does happen... they are involved in the planning. They perhaps change timetables very slightly, maybe only by three minutes, just to take account of the small delay. So that the passengers know that they will still arrive on time"*. He then mentions how there is a limit to the amount of work that can be done on main routes: *"For big constructions jobs – between Bern and Zurich – we have a maximum of two – three sites, never any more, we do not have more than four construction sites on the principal lines. It would have too big an effect on traffic"*. With the last train gone and the line "blocked" work has started (Fw: 33).

Given the effect of traffic and the location of the work in this one small example, i.e. waiting for the last train to start work and given the problematic features of the site, i.e., access problems, I was interested in how renewal work could be completed in lengthy tunnels. Moreover, what occurs when the site to be renewed in a tunnel is single line?

This can be a problem... The problems occurs when it is single line, when it is double line, for spot maintenance, then there is not a problem, it is just the same as working outside a tunnel – you step off a line to let traffic pass... But this way it is [a problem], when it is single line and there is traffic every four to five minutes, we have a problem. We then have to plan from here in Berne. If the line is not busy; then no problem. ... But there is also the problem with ventilation – there are a lot of machines, with fumes, there can be a lot of dust when moving ballast. So we use a machine that artificially injects clean air. But with tunnels and work, it has often to go through the IMM and possessions are planned for nights (Int: 34).

9.4 FORMULATING A FORMULA: THE KNOWLEDGE BASES

9.4.1 The top-down plan

In this section we find out that a concoction of historical experience, local knowledge, new technology and statistics are meshed together to form the knowledge and understanding required for maintenance and renewal.

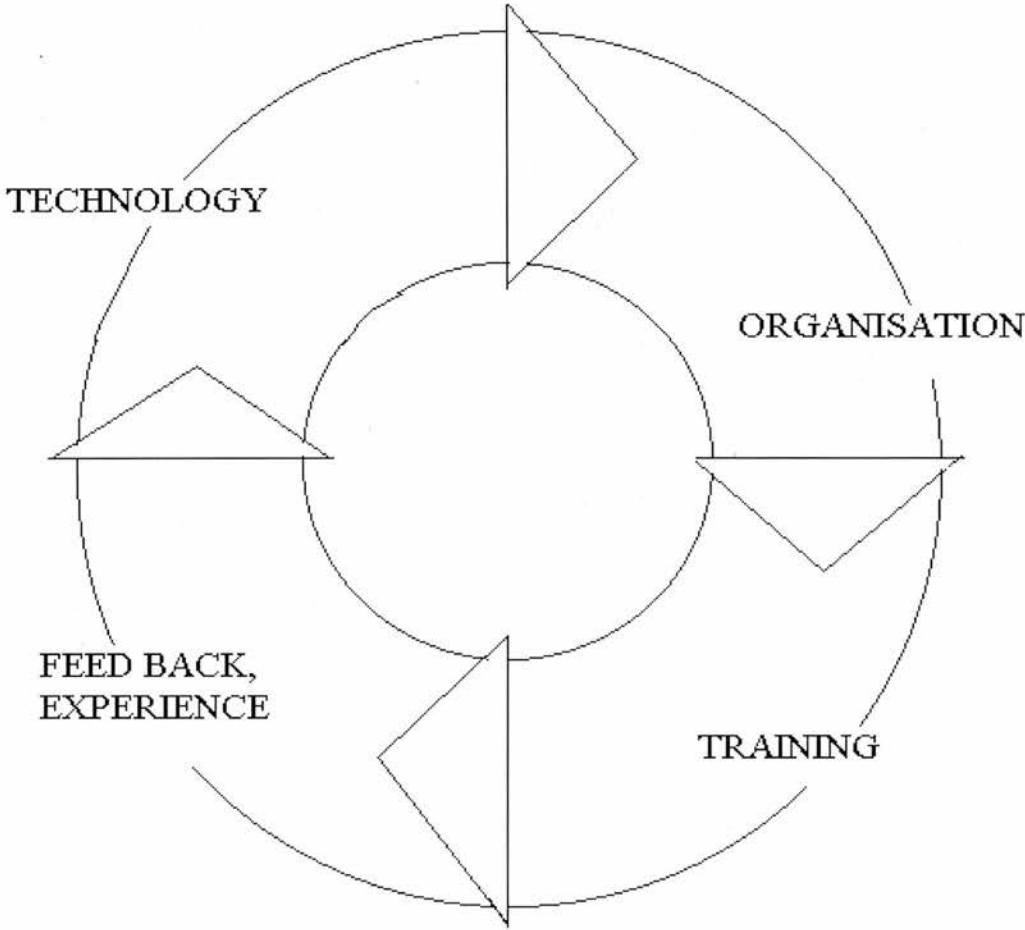


Figure 9-6 SBB Maintenance management process (source: Pfarrer, 2002: Conference paper).

The meshing together of these accumulators of data is only possible after utilising two methodological plans – the bottom up plan, and the top-down plan. The top-down plan develops from factors that are “known”. Infrastruktur, at the start of the year “knows” how much money it has for maintenance and renewal – the department can thus figure out a budget for both. The second matter is “understanding” what must be

renewed. Such understanding comes from knowledge of an asset's life-span. This knowledge is the buttress of a simple yet strict philosophy which was put to me in these words:

Knowing the normal life span tells you when to renew. You have to change at the end of an asset's life (Int: 30).

This peremptorily phrased statement shows the importance attached to knowing the conditions of assets throughout their operational life. This knowledge informs a theoretical model. In a paper produced by NPM we are told that:

The age structure of individual track elements provides the statistics for a theoretical model that determines when to renew. These statistics also show when there are increasingly strong preservation needs for an asset in its last period of life. They also tell when there are low renewals rates.⁸⁷

This theoretical / simulation model tells workers about the condition of the network as a whole, for instance it is thought that:

About 2.3% of the network must be renewed every year (Int: 30).

Or regarding precise materials, say sleepers, another said:

We know when different sleeper types start to rot. We know that the renewal rate of a wooden sleeper is 25 years, so we know that in some years we must renew some sleepers, this comes from sleepers' age and trends. This system is working; it's a question of risk (Int: 31b).

⁸⁷ This quote is from the Schweizerische Bundesbahnen (2003) published paper: "Maintenance and Renewal, Permanent Way: Processes, Responsibility, Models".

9.4.2 The bottom-up plan

Urgency is now focused on short-term regional maintenance, as opposed to long-term renewal needs. Yet similarly, this plan finds its root purpose in another uncompromising value:

You must maintain when you have to – you have to improve the structure to accommodate speed and loads (Int: 30).

By concentrating on the first half of this quote - *you must maintain when you have to* - we find that local knowledge of local contingencies is indispensable. Information pertaining to track/route idiosyncrasies must be obtained but, as one person points out:

We get the information from visual inspection – the most expensive input (Int: 33b).

Despite the burden of costs for man-power, on-foot inspection remains an integral part of the bottom-up maintenance plan:

The needs of the bottom-up plan are clearly defined and applied equally network-wide – there is an examination of conditions in the field on each track, i.e., a maintenance decision is not made at an office desk without exact knowledge of local conditions. [Furthermore] the definition of the criteria and the condition examinations in the field take place via two independent SBB internal experts. The condition examinations in the field are supported by specialists of the Technical Support Team. Main criteria of decisions are the age, tonnage, maintenance frequency, disturbance occurrence, visual evaluation as well as the results from the test car (Schweizerische Bundesbahnen, 2003) ⁸⁸

These words connect with those of an SBB worker when he was telling me about his 21 years with the company:

⁸⁸ From Schweizerische Bundesbahnen document, 2003: “Maintenance and Renewal, Permanent Way: Processes, Responsibility, Models”.

When he left school he started an apprenticeship-type programme with SBB. He progressed and eventually became a member of a team called Technical Support (defined later). He told me:

I am mainly office-based. I work Monday to Friday, early morning to late afternoon... I was offered this job because [name] wanted my experience of work on tracks at a desk where decisions are made. You make decisions on track renewal indoors, but you must know of the problems for the workers outdoors. ... I know the conditions outside, that was why they wanted me inside when decisions are made (Fw: 33).

9.4.3 Top down / bottom up – the similarities

As in the top-down plan, knowledge of the conditions *outdoors* is a valuable commodity, however, we should be wary of splitting the two plans as neatly as I have. Though the two are operated and referred to in their own right, the top-down plan's statistics and trends for understanding an asset's life-cycle come from the same sources that the bottom-up plan relies on, i.e., experience, history, visual inspection. We should also note that operating the two plans is not done in isolation. Both maintenance and renewal utilise the same knowledge, and rely on the same sources of understanding that produce the knowledge of track condition – namely the meshing together of statistics, trends and local experience. Take the following:

We ask these questions – what are the needs? What are the faults? So what do we need to do? This is the responsibility for maintenance and renewal. And in the districts, the engineers, they have to say *this district needs this, this district needs that*. And you also have statistics, so from observations and statistics you can propose what work will need to be done. And [voie ferrée personnel – permanent way workers] goes out to the different districts once a year, and with all these findings we put them into a middle plan. Here we can start saying – *this needs to be done then*. So you can get to a final point and say what needs to be done in five years. This aids budget and discussions on proposed work. We can delay work – we can ask what work is absolutely necessary? So we're adapting the programming to fit the needs (Int: 30).

It has been shown how the NPM division of Asset Management makes maintenance or renewal decisions. The methodologies utilised demand that final decisions be taken with a thorough understanding of the actual conditions in the field. By taking a closer

look at how maintenance is physically completed we also see how a *thorough understanding* is developed and utilised within the Availability and Safety division of Asset Management:

9.5 MAINTENANCE DECISION-MAKING

9.5.1 You must maintain when you have to

The priority for the Availability and Safety unit is maintenance. Accordingly, this division and a group called Technical Support abide by the proclamation *you must maintain when you have to*. This typically involves work that is planned and executed in the short-term; it is this work which is supported by “Technical Support”. At the heart of this work there is a decision-making process forged around the necessities of the network as and when they arise. At the moment we only look at how this decision-making process fits into an organisational structure. Recall part of the text in the NPM publication (Schweizerische Bundesbahnen, 2003) which, this time with my emphasis, stated:

The condition examinations in the field are supported by specialists of the Technical Support Team. Main criteria of decisions are the age, tonnage, maintenance frequency, disturbance occurrence, visual evaluation as well as the results from the test car.

This re-reading makes it plain that the relationship between those “in the field” and the “Technical Support” team is critical. Within Technical Support there are six functional positions headed by individuals – these six functions are given in fig. 9-7 as sub-departments.

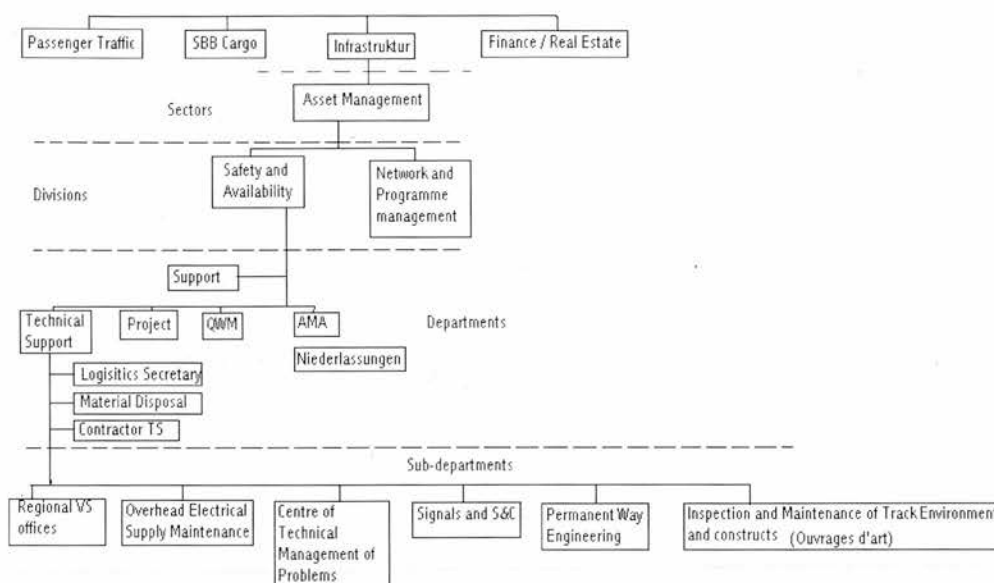


Figure 9-7 Availability and Safety: the sub-departments (author's sketch).

The Technical Support teams support and assist in the decision-making taken by the different teams of the different sub-departments. Of these sub-departments, two are of direct interest in this thesis:

- **Inspection and Maintenance of Track Environment and Structures** (Ouvrages d'art). Here there are four different teams which have the following tasks: 1) one inspects the condition of the track environment, this involves inspection of track components (sleepers, bolts... etc), concrete structures such as tunnels and bridges, this team also inspect embankments and is known in French as Teams d'inspection des ouvrages. Another team (2), are construction engineers who repair faults. Two other teams inspect other environmental matters they are: 3) teams for weed killing (désherbage); 4) and teams to maintain forests close to the track (forêt).
- **Permanent Way Engineering** (Voie Ferrée; V.f.) (or, in German: Fahrbahn). The maintenance of the permanent way includes the following three divisions: 1. P-way spot-maintenance teams (Ingénieurs V.f.); 2. Ultrasonic groups (ultrason, groupes d'auscultation); 3. Clearance within tunnels and bridges (profils d'espace libre).

At this moment we need to know that these individual teams work within one of the 23 districts that the SBB network has been broken down into. The team charged with the inspection of the track's environment (see fig.9-8), known in French as *Teams*

*d'inspection des ouvrages*⁸⁹; and (2) the permanent way engineering teams involved with spot maintenance and ultrasonic inspection are of interest to us.

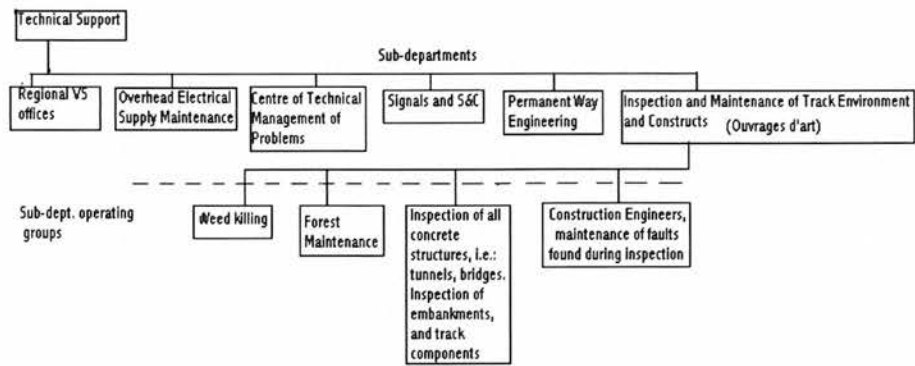


Figure 9-8 Operating groups of the ouvrage d'art.

9.5.2 Teams d'inspection des ouvrages: the organisational structure on paper

For this type of work Switzerland has been divided into thirds and within each third there are several of the 23 districts. Each third has a central Technical Support Office (see fig. 9-9).

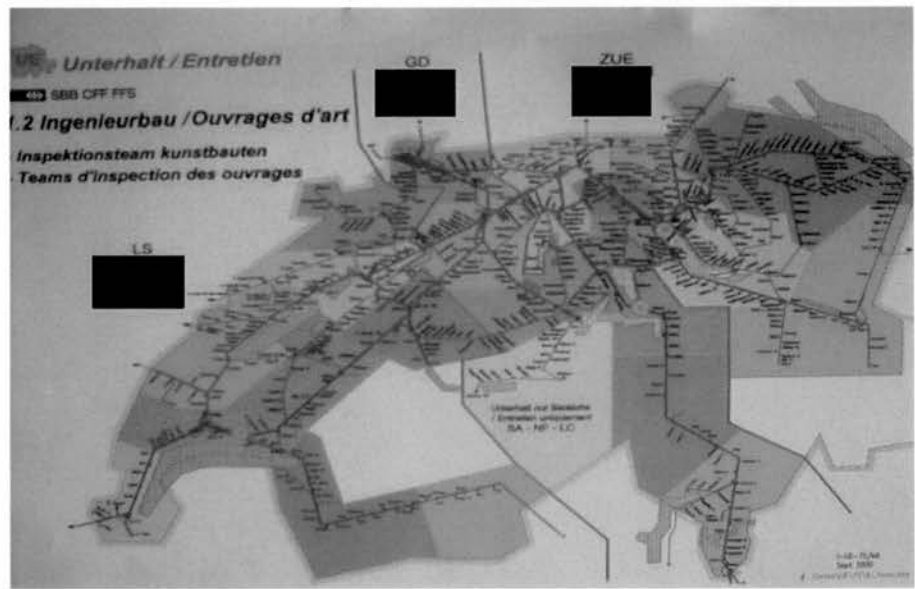


Figure 9-9 Ouvrage d'art districts

⁸⁹ Here, and from here on, I use the French *inspection des ouvrages* when referring to this department simply because it is easier to read and not as clumsy as continually referring to “Inspection of track environment and all concrete structures”.

This set-up requires each of the 23 inspection des ouvrages teams to co-ordinate and plan *their* work as required from smaller offices. Such offices in the western section are Bienne, Delémont, Fribourg, or Neuchâtel.

Organising work to accommodate the needs unique to locations as and when required, one presumes, requires a significant degree of foresight, instilled by experience. This supposition stems entirely from the words of the NPM publication: a *main criterion of decision-making is conducted in the field by visual evaluation*. But, as a corollary, these words give rise to another assumption: learning the behaviour and trends of permanent way assets within different locations cannot be done over night. Each section of line, remember, has an existing memory that can have its own problems that are generally learnt about over time. Thus, to adhere to the methodologies required, such as the bottom-up plan, a key role must exist for workers with a thorough understanding of *their* area.

Through extensive reference to fieldwork notes, let us now look at the role of experience and tacit knowledge, the role of front-line decision-making, and the autonomy of district workers during visual inspection.

9.6 ASSESSING ASSUMPTIONS AND FIELDWORK NOTES

9.6.1 Teams d'inspection des ouvrages: walking seven kilometres

On a blisteringly hot morning, in the shadow of the rolling green banks of the Jura mountains, I stand on the platform of a mainline station where I have donned a bright orange vest; my compulsory safety gear. I am with a similarly dressed SBB worker called Markus.

Markus has been with SBB for "23 years, SBB is a good company, it's a big company" and he "like[s his] work a lot". He is a member of this district's inspection team of the ouvrages d'art. He walks an average "20 kilometres a weeks, but it can change, the centre of planning can change tasks weekly, [he goes] to places where problems have been reported, perhaps by trains drivers or that are due for a revisit".

During the first few metres of our walk I ask Markus about his work. When he is working he is *"looking at everything, the conditions of the overheads, the surroundings, if stones have fallen from hills and mountain sides, the condition of the ballast, rails, sleepers, and fencing. I see if things are tidy"*.

I ask him about the relevance of his 23 years of work on the railway: is experience important? He tells me that though he has been with SBB for that long, he has only been walking in this district for four years. But yes, experience is important: *"By seeing and knowing what to see, you see what components are functioning and what are not functioning. ... I have a good idea where problems will be"*.

We have only covered a few metres before we come to the entrance of a tunnel that burrows away deep below a huge mountain. When I look into it I see no daylight from the opposite end. Asking Markus how long it is, he shows me a small map and points at the tunnel on the paper. A figure tells me that it is over 1500metres long (about one mile long).

In the tunnel Markus uses a torch which proved to be extremely handy from my point of view as a researcher. Earlier when Markus had told me he looks at "everything" I could only guess at what he really meant, moreover, he had also said that he knew *where* problems were *likely* to occur, so clearly the problem was - how was I to know when he would be looking at a potential problem area? In the tunnel this conundrum was solved.

The beam of his torch indicated to me where he was looking – it gave me *his* line of vision - if only for 1500m of 7km. But from then on (outside the tunnel) I was able to guess where he was looking. The torch's beam acted as a template I could use to "follow" Markus' line of vision.

The torch light in the tunnel darted and skipped over the sleepers, the pads, the ballast at quite a speed, not resting for a second – it certainly moved too fast for me to be able to assess anything. The light danced sporadically from the rail nearest to us to the rail furthest from us, to the walls of the tunnel on either side, to the apex of the ceiling and back to the ground.

As we were doing this Markus suddenly raised an arm and said "train". We stepped up the pace till we reached a recess in the tunnel wall that gave us a point of safety. When in the recess we waited for the train to come and it was during this period of waiting that I became acutely aware of something quite disconcerting. Not only was I surprised at the length of time it took the train to approach us and come into view, but I was totally astounded that Markus knew it was coming in the first place, for I only heard its approach when we were in the recess which was some moments since Markus first signalled its approach. This was not only going to puzzle me whilst the next few trains passed, but also made me question the quality of my own hearing. How did Markus hear the trains coming?

In total seven trains passed us when we were in the tunnel, and until the fifth Markus had consistently warned me in advance when a train was approaching and consistently well before I could even hear a train. Yet eventually I found out: Markus knew trains were approaching prior to seeing them (and hearing them) in the tunnel, because when a train enters it, the air pressure is affected and your ears pop ever so lightly. Given the length of the tunnel, ears pop very gently (and to me, at first, quite unnoticeably) some time before you hear the train, thus there was time to get to a recess which were never more than 45 paces apart.



Figure 9-10 Length of route walked with Markus (author's photograph).

Further on (still in the tunnel) Markus stops and focuses the light on an area where water is dripping. He shines the torch on numerous parts of the wall where a damp patch is clearly observable. I become aware that Markus, apart from just looking is also listening keenly. At times he looks away from the patch, head slightly bowed with an ear directed to the scene of analysis. Conscious of this, I refrain from asking questions and feel myself trying to control my breathing in an effort to keep the quietness as pure as possible. Markus then moves on only a matter of paces before he does the same. Then when he starts walking again, I ask if there is a problem. He hesitates for a moment before saying it is ok. He simply explains he was listening to the dripping to see how fast it was dripping, or how heavy it sounded. In any case he maintains that it was ok.



Figure 9-11 Rail in good condition (author's photograph).

We exit the tunnel with still a few kilometres to go. I am particularly interested in the role of "listening", considering the dripping episode in the tunnel. I ask him if he often *listens for potential problems*? He tells me "*when a train goes by I watch and listen for sounds; heavy sounds that clank, (at which point he slams a fist into the palm of his hand repeatedly 5-6 times), I listen for heavy clanks at welds*"

We move on in the blazing sunshine and I recall the dancing torchlight in the tunnel and imagine Markus's eyes darting over the environment; swiftly surveying the land like a bird of prey hovering above a field in search of its next meal. Soon he is not happy with something. He is looking at clips and a seat that pin the rail to a sleeper – in the end he records on paper that the sleeper and clips need attention. He points the problem out to me: although there is cracking over the whole of the wooden sleeper – the cracking where the rail is attached looks quite pronounced around the pad between the rail and the sleeper. Markus doesn't like it, he takes the location from a nearby sign and he tells me he will call colleagues.

At the end of the walk Markus records his work onto a notepad – "*there were not many problems today*", he tells me (Fw: 30).

During this walk I saw how experience underpinned a specific form of tacit knowledge. For instance, Markus had developed an idea of where problems can occur, and he had even developed an idea of how dripping should sound when things are fine within tunnels.

Some days later I was given a glimpse of the autonomous working methods of district workers, like Markus, when I spoke to a senior SBB member of staff. For instance, I had asked Markus, when we were walking the track if it had been "walked" two weeks ago, he had said no, it was a little longer than that. Regarding what others had said: that every line is walked every two weeks (Int: 30; Int: 33), I wanted the senior SBB worker to confirm or correct my information. He said:

They should be walking the line every two weeks... perhaps in their district they have decided that walks on some lines can be reduced. I would think that decision will be because of traffic. Freight has reduced... walking should refer to the rate of traffic, tonnage... if tonnage increases, walking must increase. If the walking on some lines has gone down, traffic has reduced (Int: 34).

The knowledge I had was correct, but the comment brought into focus a sense of autonomy that these workers have. A significant degree of decentralisation permitted frontline decision-making which is underpinned by local contingencies.

9.7 THE UP-KEEP OF THE PERMANENT WAY

9.7.1 Spot-maintenance

Maintenance of the permanent way is split into three areas (see fig. 9–12): spot-maintenance teams, ultrasonic testing, and engineers concerned with tunnel and bridge clearance. This thesis focuses attention on spot-maintenance and ultrasonic testing.

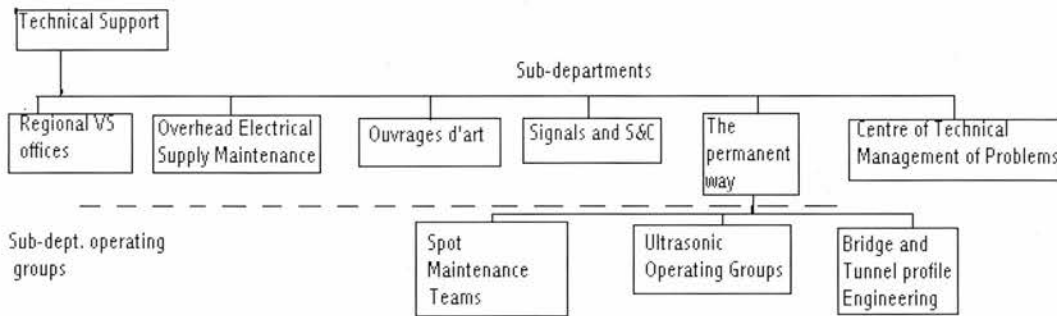


Figure 9-12 Sub-departments of the Permanent Way (author's sketch).

For the spot-maintenance, Switzerland is split into six sections with each containing a technical support office. The role of the Technical Support teams is outlined:

For all spot maintenance interventions [teams] have the responsibility, the competence and the money to take the necessary measures. The Technical Support supplies them with engineering expertise and disposes of the necessary funds to order major maintenance work like re-railing entire sections (Pfarrer, 2002: Conference paper).

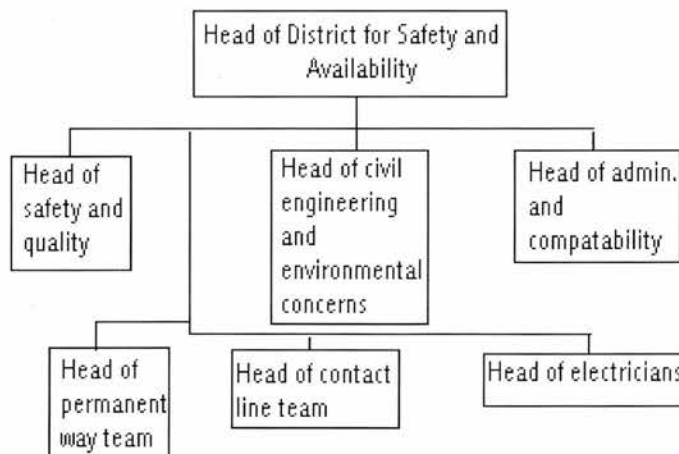


Figure 9-13 The structure of spot-maintenance in one district (author's sketch).

This organisational structure (in fig. 9–13) of spot-maintenance is replicated throughout the SBB network, with only some slight changes that vary from district to district:

Yes, yes it is the same structure within each of the 23 districts, but there are changes in the number of people in each department. In Zurich compared to Delémont where there are not so much overheads, there are a different number of teams. The size of the teams... they vary... they are of various sizes which correspond to the needs of the district they work in (Int: 34).

In fig. 9-13, the box labelled “head of permanent way team” is the one that interests us. Permanent way teams undertake immediate, small work that needs to be done to the permanent way. One team maintains rails and sleepers and the related components, another maintains switches and crossings and level crossings; the last team maintains signalling. Tasks for the first team therefore include applying preservative to wooden sleepers, replacing pads, chairs, renewing clips, bolts, screws, and renewing short sections of rail. The task for the second team includes measuring gauges at switches and crossings (S&Cs).

The idea of decision-making in the field as “decentralised” is also important if we accept another matter: complex organisations such as a rail business distribute workers over a wide geographical expanse, thus a significant degree of decentralised decision-making, one presumes, must be required. In the following set of notes, I assess this assumption.

9.7.2 Permanent way spot maintenance: checking a switch and crossing installation

The work that is taking place this morning is the measurement of one set of S&C. Hans introduces me to Joel, a trainee who is going to measure the S&C.

Joel shows me a document that lists and illustrates several types of S&C. By referring to the diagram and referring to the rail type and profile, we find the maximum and minimum tolerances of the gauge for each section of this S&C. After measuring the gauge at seven different points, Joel records the results. He then refers to a master sheet that states exactly what the measurement should be for each section – below

this it then states what the maximum and minimum tolerances can be. It is typically -2 to +10mm.

The gauge however, (see fig. 9–14) is not the only measurement that Hans uses: he tells me how he has been in the industry for 23 years (coincidentally the same length of time as Markus from Fw: 30) – he knows by looking when something is wrong and by way of example he shows me part of a manganese S&C where it does not come to a pointed, straight end. Instead it is blunted and appears bashed – something he says he doesn't like – and it is something he has already noted and has planned work for.

He gives me a further example of knowing when something is right or wrong. This section of track is very busy and a lot of traffic is operating. When a train passes near us, Hans demonstrates how he can tell if things are ok. He covers his eyes with his hands and repeats the word – "*listen, listen*"... he can hear when something is wrong.



Figure 9-14 The measurement gauge (author's photograph).

The measuring takes about 30mins – we stop and start mainly for traffic reasons. The S&C measurement shows that all the sections are within the tolerances – the most the measurement is out of the exact / ideal measure is two millimetres. Hans says that the S&C is in good condition. But at another S&C things are different, one of the

measurements shows the gauge to be five millimetres outside the tolerance zone and moreover, the traffic over this S&C travels at high speed.



Figure 9-15 Close-up of measurement gauge (author's photograph).

I ask what actions will be taken: *"It will be fixed tomorrow, if not tomorrow only a little time after that"*. However, if there were a lot of problems, *"it takes more planning – it goes to control for planning"*.

For fixing the smaller problems, the facilities are shown to me. By the station there are numerous buildings, yards, and garages. Each hold and store specific material for all aspects of maintaining the network in this district. This includes storage of tractors, trimmers, weed killing drums, warning signs, and equipment such as clamps, spades, large spanners and heavy machinery. For smaller permanent way components I am shown inside an old carriage which has been converted into a storage room. Lining the walls are small green baskets.



Figure 9-16 Interior of converted carriage as a stock room (author's photograph).

Within each there are either: bolts, nuts, plates, pads, or clips and many other smaller items. Each basket is also colour coded – the codes refer to a sign on the door of the carriage as you enter. There are four colours, and each colour designates the time when each basket should be replenished. Each colour is a symbol of the degree of urgency. It is, Hans tells me, "*a very efficient method of controlling stock*" and managing "*risk*". When we go to other areas of the complex I see the same code for much larger equipment, such as sleepers, rubber walkways for stations, and indeed rail for normal line and S&Cs. In the yard there is a large area where there are some sections of rail.

Hans shows me how these levels are maintained. He says how it is not one person's responsibility to maintain the levels – it is everyone's. He explains this by taking me to a room that is equipped with one desk, one computer, some files. Every worker has access to the computer.



Figure 9-17 Colour coded drawers of components (author's photograph).



Figure 9-18 Replacement sections of rail in yard (author's photograph).

It is where they order supplies as and when required. In a different room I am given a glimpse into the important role of history. There are several filing cabinets: Hans opens one and takes out one folder and shows me the contents. It is lengthy roll of paper once it is unfolded. At the top right there is a name of a route and beside it is the date 1985. The paper has a key for the symbols that are printed on it. Such symbols at different points of the paper show when and where on the route ballast was renewed, rails were renewed, sleepers were renewed and any maintenance work at S&Cs and plain rail was done. Basically, the paper is a map of the route which details the history of all work that has been done on it since 1985. He shows me other files which detail work on other routes which go back even further, some 30 years. When showing me the maps, Hans confirms my thoughts on the importance of recording all work on a route, for he tells me: *"to know what work was done and when is very important, it helps when decisions have to be made for today or in the future"*.

Beside the office block, there is another building – it has a kitchen, a communal area, a shower and wash area. This building and this area looks new; Hans tells me it has been in use for three years. I comment on how good the facilities look; he tells me how it helps *"motivation, people have to enjoy coming to work; that is very important"* (Fw: 32).

The size of the complex that I visited was considerable: it had to be to store the many components required for spot-maintenance. The size of this complex alone suggested to me that spot-maintenance decision-making was an extensive, critical process done within the districts with a degree of independence from central offices. Take the following quote regarding the role of the *man in the district*:

We plan in the long term for renewal and plan in the short term for maintenance. Spot maintenance is done on sharp curves [for example] - following up ultrasonics when we have a defect. The man in the district has the responsibility and the means to change rail – lengths are approximately 6 metres – there's no need for permission and he has the stock for this. According to their experience they maintain their stock according to historical need... We know that every year we have so many rail replacements, so we plan and take the costs and calculate it from the budget (Int: 30).

Likewise, I asked another if he thought that this type of decision-making was a form of decentralisation. This is how the conversation went:

R: Yes, we train people; we give them the required competencies. We have delegated a lot of competencies to the front. This is required for effective spot-maintenance. They have the ability and the competencies required to realise what needs done and when. If it is a large piece of work then it takes planning...

I: And that work is planned here (SBB HQ) with (name of SBB worker)?

R: Yes, to plan work, organise traffic, machinery. But for smaller work, it is essential for the team to do it when it is required (Int: 34).

Relying on experience to execute frontline decision-making during spot-maintenance is a necessity for effective operations and high levels of safety and availability. In the next section regarding ultrasonic testing we see another critical necessity: the role of the experienced team for decision-making.

9.7.3 Ultrasonic testing: The organisational structure on paper

Though essentially an inspection technique, ultrasonic testing is located here instead of with *ouvrages d'art* inspection team because, unlike the *ouvrages d'art*, UT is concerned with one component of the permanent-way – the rail – and not the entire environment. The SBB network for UT organisation has been split into three sections, with the boundaries between each, again, running from north to south. In the west of the country the technical support office is in Lausanne, the others are in Zurich and Luzern.

The principle that underpins ultrasonic testing (UT) frequency on the SBB network is tonnage carried. SBB has a clear understanding of how much tonnage is carried on every section of its entire network. A map of the network has been produced and lengths of track are colour coded in line with the amount of tonnage that each section of track supports daily. The network is thus broken down into four maximum tonnage categories: 25,000; 50,000; 75,000; and 100,000 tonnes per day. Depending on the level of tonnage a line carries, UT is completed at a particular frequency.

By looking closely at how UT is structured in the west of the country (which we can use as a template for how it is organised in the remaining sections - Int: 34), we see the significant role that UT has on the SBB network.

In the western section, the network is broken down further into nine branch offices (succursales) and named after the mainline station. The nine are: Lausanne, Genève, Neuchâtel, Bienne, Fribourg, Delémont, Bern, St Maurice, and Brig. Within each branch, data is known about all the lines, the tonnage carried per day, the rail type (i.e. profile), the length of rail in kilometres between stations, and the amount of S&C on that length. Furthermore, it is noted how each length of line and each switch is ultrasonically tested– which is either by manual means, i.e., a test trolley (see fig. 9–19) or by a rail based testing car. Additionally, each branch has been given a specific time of the year when hand testing is done (see 9-19).

Branch	Test period (month)
Lausanne	January & February
Geneva	February
Neuchatel	February and May
Biel/Bienne	May
Fribourg	July
Delemont	September
Bern	June
St Maurice	September
Brig	August



Figure 9-19 Branch offices and train-based testing time, and picture of manual test trolley (author’s sketch and photograph).

There is supplementary testing that occurs every year by means of a rail based ultrasonic test car. In March the rail testing car from one private company is operated over the entire western section. It is operated by the private contractor over a period of 15 nights. Then every fault that is found by the rail test car is checked manually by the UT teams with testing trolleys during April. The same process then occurs later in the year (September), but with a different rail based testing car from a different company. Once more, any faults picked up by the car are then re-assessed by the team via the test trolley in October. In November each route section is then subject to a “Contrôle Partiel” – an end of term check-up. In December, no testing is done at all on the SBB network, due to weather conditions.

9.7.4 Ultrasonic testing: the role of the team

Prior to seeing UT in practice it was pointed out to me that an experienced team is seen as a valuable commodity, so when changing a group's structure without proper regard, important dynamics may be lost:

They [the teams] are very good at their job, if you change things rapidly it could be a catastrophe, it takes a lot of time to make a little change (Int: 33a).

It was suggested that experience has bred a high level of trust in the team's decision-making process. For instance, if a team finds a serious fault they contact their supervisor, who contacts the controller of traffic and demands the cessation of traffic operating on that line. If the controller of traffic questions this, she or he will then contact the manager of all UT in Switzerland, who told me:

When he [the team member who found the fault] says no trains, I trust him, he means no trains! He has the experience (Int: 33a).

When reading the following fieldwork notes we should keep in mind the emphasis that is placed on the role of the experienced team.

9.7.5 Ultrasonic operation: in practice (Testing an S&C and déjà vu)

I have been driven to a small town's train station by an SBB worker where a switch and crossing is due for a test. At the scene I meet up with Stephan. Stephan is the supervisor of the team. Unlike other organisation for railway maintenance, there is not an UT team per district. There are not 23 UT teams. Instead, there are three which cover several districts in each third. Stephan introduces me to the men that are here; there are five SBB workers altogether including Stephan. There are two men for look-out - one will stand some distance behind us, the other some distance ahead of us. The route we are on is a principal line and the trains travel very fast. The other two men, along with Stephan comprise the "UT" team – it is a three man team.

The equipment that the men are using is a hand-pushed test trolley which is similar to the walking sticks used in Britain. The display pack from which the men read the feedback are identical (see fig. 9-20).



Figure 9-20 Identical UT digital packs in Switzerland (left) and Britain (right picture) (author's photographs).

The UT team firstly talk to me about the principles of UT. Stephan has a piece of chalk and has scribbled on a sleeper the numbers 0° and 070° - beneath these digits he has drawn a plain rectangle with a vertical line cutting down the breadth, and another cutting down at an angle. He was clearly referring to the angle that the pulse is fired into the rail. I know exactly what he is referring to, but he is keen that I understand precisely. He uses a pen to show me the direction of the pulse from each probe as it leaves the trolley. Stephan's method of explanation is virtually identical to the way UT operators explained the same topic to me in Britain. Moreover, the men are all keen to

shown me the importance of keeping the stick placed on the centre line (right at the apex of the rail head). Again, in a process similar to the one I saw in Britain, the men explain the concept of rail depth – by shifting the stick to the side they hit the underside of the rail head and thus show me the feedback on the display, and then once they have shifted it back to the centre they shown me how it should look.

They work closely together. Stephan said: "*they must be together, one to use [the trolley] and watch the display, and one to watch the rail the where [the trolley] is covering it. They are looking at different parts; they listen for alarm for problem*". I ask Stephan more about the task of the man who is looking at the rail. He is watching the rail to notice such things as badly drilled bolt holes, one of which is pointed out to me by Andreas. The bolt hole he is showing me has quite a bit of lipping and I can see the threads of the drilled hole on the side of the rail web. This, Stephan says, is what Andreas is looking for: he has to notice these things.

Continuing the same line of enquiry, I ask more about team work. The work between members of an UT group, Stephan tells me: "*is important, very important*". One of the men has worked with him for four years, the other three. And he continues, "*it is important to keep the group stable – you need stability and experience*" – and when a new person starts – "*they have to take the job seriously, because they must always be looking*".

We continue examining the rail, and the team consistently point out to me the rail depth signature when the 0-degree or 070-degree probes hits a bolt hole. But they also show me something new.

In specific places, the rail base is raised from the ground where the switch blade meets the stock rail - it is still flush at the top with the stock rail, but the depth of the rail is shorter. It is raised as there is an area that the switch blade slides onto (see fig. 9 – 22). However, because the rail is raised and to keep it raised there are some bolts hidden to the naked eye that prop it up, thus when the ultrasound wave hits this, it can look like a problem on the digital packs.

The team, again are keen to point out to me that knowing that these bolts exist is an important process of UT. Often they can be construed as problems, but knowing when

the pulse will hit the bolts here, and knowing the difference of this from a real problem is important (Fw: 31).

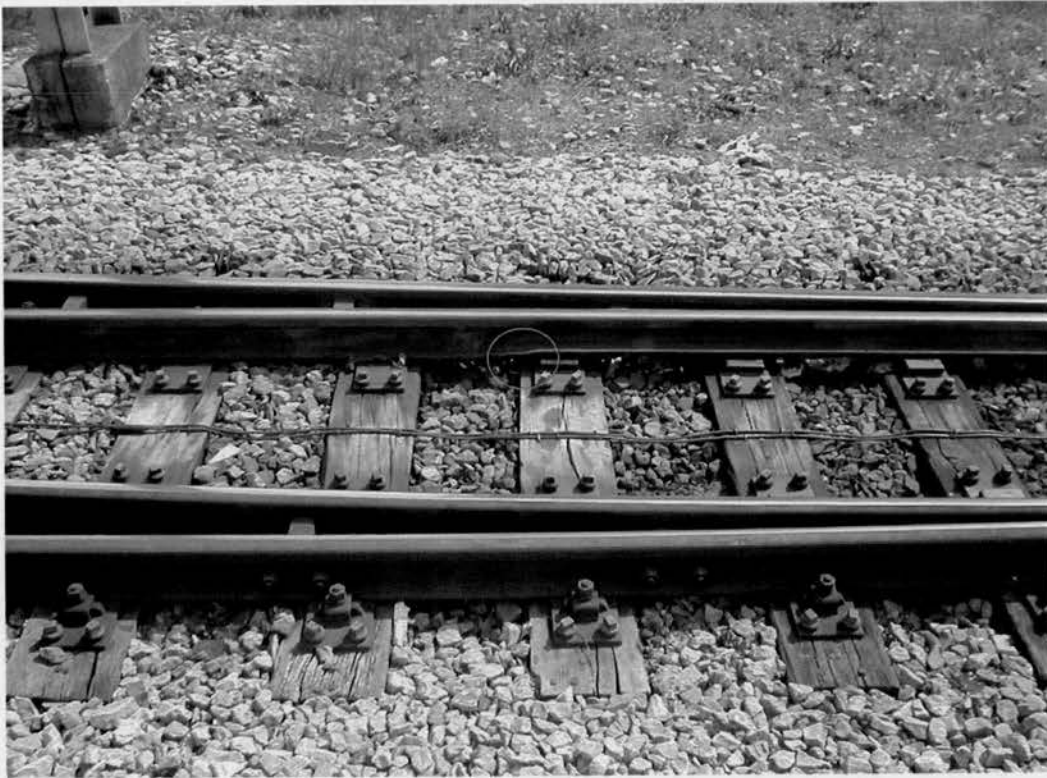


Figure 9-21 Risen switch blade and hidden bolts (author's photograph).

The afternoon I spent with Stephan and his team of UT operators was as intriguing as it was familiar. Despite the language differences; despite the change in environment, the scene presented to me was uncannily familiar. The equipment was virtually identical; the size of team, likewise.

9.8 A SENSE OF BELONGING AND 23 DISTRICTS

9.8.1 Example one: The track recording car

Dividing the country into 23 districts and allocating teams to these districts has aided the development of a certain sense of belonging among the teams. This was demonstrated to me during my time with the spot maintenance workers who developed location-specific “knowledge” of the problem areas within the district they

work in. And like Markus, they have developed an implicit understanding of their district, which appears to generate feelings of ownership and pride:

It is important to keep the same team – this is very important, they take a special pride in their rail region and this is a very important function for the safety of the rail (Int: 33a).

Elsewhere, but on the same point, a worker told me how he was proud to wear clothing that displayed the SBB logo. He even told me about an occasion when he was standing on a station platform waiting for a train that had been delayed and was embarrassed at the excuse given over the public address system (Fw: 33). Given the degree of pride that SBB workers appear to have in working for the company, I now take a closer look at the organisational structure of maintenance to assess its impact on workers and teams.

The station that I and two others are standing at is at the tip of a large stretch of water, and the task today is to circumnavigate this large lake in a track recording car. We are due to stop for lunch at the opposite tip, before making the return journey along the opposite bank arriving back at this station in the late afternoon.

The track recording car arrives. It is two carriages long and the one we are on looks like no other I have ever seen.

To start, deconstruct every preconceived idea of a normal carriage, and fill the empty shell with one partition in the centre of the carriage so it is split in two. Then in one half insert more partitions until one half of the carriage has cubicles of differing sizes – one contains a toilet, another a small kitchen and the other, A small table and chairs. The other half of the carriage, which is basically one large area, is where the work is done. There is a large desk here and three seats are placed around it. The windows are larger than normal so viewing the track is simple. On the wall that creates the partition we have a multitude of data processing units and monitors.

When we boarded the train I met three other men. Throughout the entire journey two of them were monitoring the screens relentlessly; glancing at digital displays, and peering conscientiously at the track as it tailed off behind us. The other man sat steadfastly in the same seat by the side of the carriage staring intently below at the track that the train passed over. When we passed through a tunnel, he pressed one

button, when we passed over a bridge he pressed another, when we passed over a switch and crossing, another, and likewise for passing through a station, or over a level crossing.



Figure 9-22 Some of the several databases (author's photograph).

Two men are at the desk: their interest is directed at graph paper which started to scroll across the table from a feeding slit in the table as the train moved.

The paper is divided into sections (gauge measurement, cant deficiency for example) and for each section a continuous reading is outputted on to the paper in a form which I liken to the wavelengths on a medical cardiograph. Each of the sections have tolerance levels that must not be breached, thus it is the task of the men analysing the findings to act on any breached tolerances or tolerances that are nearly hit.

During the entire day I only saw one tolerance that was breached; the immediate response was a quick and short discussion between all the men except the one by the window, the area of the paper was underlined thickly with the pencil and then a phone call was made.

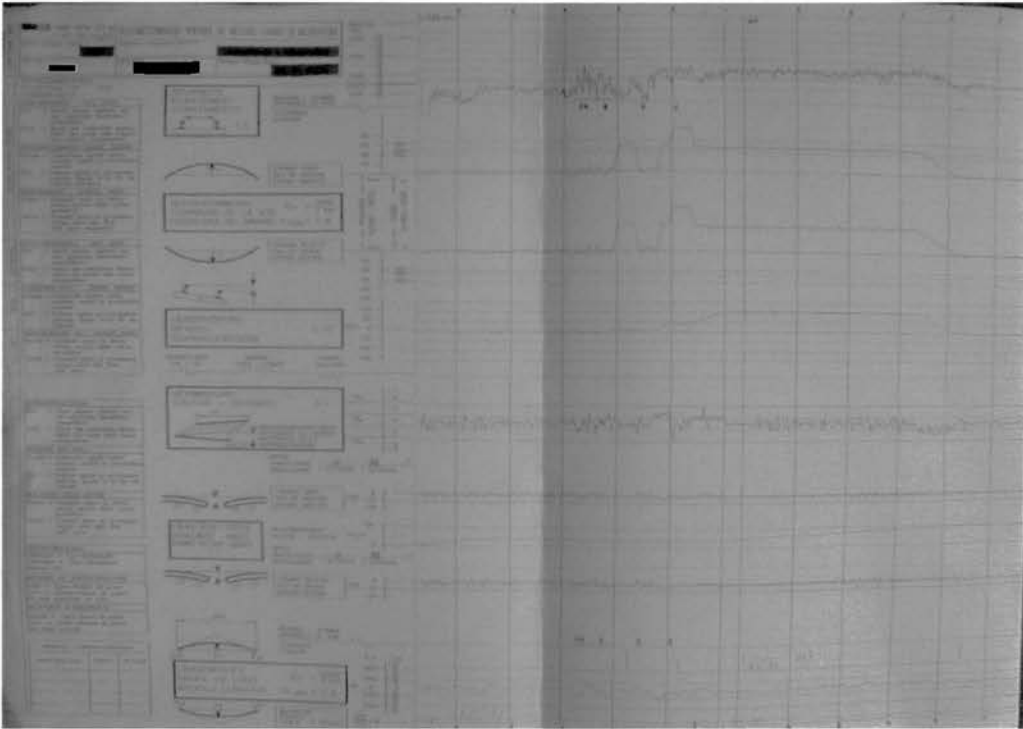


Figure 9-23 The lay-out of the track recording car results on paper (author's photograph).



Figure 9-24 The desk, out of which, the new graph is fed onto for analysis (author's photograph).

When we were approximately half way through the morning we came to a halt at a station and the two men I had met first thing gathered up the papers and left the train.

Two others replaced them and took up the identical duties of those that had just been relieved. The rest of the men on the train remained unchanged. Despite the change in individuals the scenario was indistinguishable to earlier. These men spent the majority of the day with us; it was not until sometime after lunch time that they too left the train also, again packing up all the paper work that they dealt with. At this point the original men who I had met first thing boarded the train again, the familiar activity ensued: unpacking papers, underlining potential problems, and packing all the papers at the end (Fw: 34).

In the following set of fieldwork notes, I again detail similar activities.

9.8.2 Example two: Track Renewal Inspection

I have met up with a party of eight. There are three men from Technical Support and, of the others, two will act as look-outs. One of the men from Technical Support shows me the plan for the day. We have about eight different locations to visit. He tells me how there are several districts in his section and that we will be visiting two of them. There will be an inspection of plain rail, rail on curves, and S&Cs, and rails at stations⁹⁰.

At this location we are on and off the track as it's very busy. However, when on it, Boris (of Technical Support) uses a long handled, blunted pick-axe type-tool to hammer at the bolts that are attached to the rail seat. He hammers at bolts at every other sleeper. The other three men and the other two from Technical Support scrutinise different areas.

Some areas of the permanent way are walked past almost nonchalantly whilst others are keenly inspected. At the end of the inspection the men come together and Andreas and Boris have a long discussion during which they refer to flowcharts and tables. Eventually they reach a final figure of "32". As it is below 50 it is given a "priority two". Above 50, and the track needs quick attention.

⁹⁰ I will just refer to the activity that ensued at one site as it was roughly duplicated throughout the day at the other sites.

This was roughly the process for the entire day. However, the point for now is that in the late morning, three of the men left us and were replaced by another three men. Despite this change the activity at each of the remaining sites remained the same. Conscious of the change in personnel I ask questions about it. The three men who were with us were the permanent way team for the district we are in – i.e., one of the 23. Andreas tells me that when they left us, we were leaving their district. We had crossed a boundary and entered a new district – hence the role of the other men – they were the team for the district that we had moved into (Fw: 36).

I noted the term that Andreas had used when describing the reason for the change in personnel: it was “their” district. It was similar terminology when I asked about the reason for the changes in the track recording car, where I was told simply, that the car had:

...crossed a [district] boundary and they [the men] join and leave us when we enter or leave their district (Fw: 34).

Likewise, another said:

[The first man in the morning] had results for his district, and [he, the man in the afternoon] had results for his district (Fw: 35).

Whether or not dividing the organisation of SBB’s network into 23 districts was designed to encourage a sense of belonging was intentional or otherwise, the workers with whom I spent time with referred to specific districts as “his”, or “theirs”, and indeed one member of Technical Support spoke of the districts in “my” section, suggesting to me that they did indeed have a sense of belonging to the districts. This argument gains favour when we remember how a UT worker spoke of the teams “taking pride in their region”. But it is a little tenuous to simply state that where a worker works, he or she will have a sense of pride *de facto*. We need to know how such feelings develop.

9.9 CONSTRUCTING OWNERSHIP: FAMILIARITY BREEDS COMMAND

9.9.1 The sources of sagacity

In the spot-maintenance example we saw how an S&C was measured but, more importantly, we saw who measured it – a trainee. He was given the equipment, he was given the relevant paper work, and he was supervised in everything that he did from actual measurement of the S&C to the boxes he ticked on the paper. More importantly this was done in a real-life situation. This was not the only example of learning in the field that I witnessed. For track renewal inspection, there were three members of Technical Support, two of the team, Andreas and Boris, were senior and were the lead decision-makers. Whilst accommodating the input from the others, it was they who decided on the final “priority” by working with flowcharts and figures. Of interest however, is the role of the third Technical Support member. He was a trainee who:

Has been with SBB for nine months, he has to come out [on to site] with us and see... We don't have people just from university; he has to go on site, to know and to see the way work is done. ... We think it takes about two years this way, to learn how to work effectively (Fw: 36).

These were the only two examples of training that I witnessed during my fieldwork, yet the processes I saw tied into the words spoken by another when he referred to his own training some years ago:

When I left school I was taken on at 16 and I started programme – in English I think it is apprenticeship, I did this for three years, and then one year out for compulsory military training. When I came back my training continued still... I went to a district, my work was with the track and I trained with other people there, but they did not work with the track. They worked with operating traffic, signal maintenance, inspection. This was so we could all see what else happens when operating a railway network (Fw: 33).

Correspondingly, another worker gives a succinct outline of how training is structured for those involved with the permanent way:

For the track environment, training is split into three faculties. One faculty for the track people, one faculty for the overhead line, one faculty for safety equipment, S&Cs and their electrical supply, they are really electricians. ... For training in these zones the schedule is

three years, for one year the apprentice will join a team of other apprentices where their progress will be recorded. They are then distributed to teams in the districts of the country. The teams maybe take on one or two apprentices; here they are given a program of points they have to learn. At the end they are examined, and become qualified track builders (Int: 34).

Whilst structured learning sensitises individuals to specific issues – completing paper work; using measuring devices and other tools; understanding the role of others – it was suggested that other skills can only be learnt in the field, e.g., dampness patterns in tunnels, and knowing what to listen for when drips are falling, and what to listen for when trains pass over S&Cs. In essence the learning period for railway maintenance workers is continuous. It is, arguably, this process whereby individuals come to “know” an area that enables them to generate feelings of ownership and belonging. Take the next findings which describe the relationship between experience and training for the ultrasonic operators:

For UT training, team members are taught the relevant principles as part of a week-long course by a representative of a training company. With the appropriate equipment, the representative visits the “third” of Switzerland where the team works. Then each team member is tested on their ability to UT various pieces of rail. A refresher course is conducted approximately every four years (Int: 33a). This length of time is deemed suitable because UT remains relatively unchanged:

The technique is the same, but it is useful to refresh the principles (Int: 33a).

The length of time between refreshers courses is also thought suitable because:

Experience is more important than training (Int: 33).

Examining the construction of knowledge that shapes necessary decision-making has referred us to the role of experience. The wealth of knowledge that these workers have accumulated has seen them develop an ardent sense of familiarity with a district which in turn suggests how feelings of ownership to a district and pride are cultivated.

9.10 FINAL COMPARISONS

9.10.1 Paperwork and confidence

This section stems entirely from a simple observation that I noted on several occasion throughout my fieldwork.

In my British-based fieldwork, I referred to the amount of paperwork that was required to be completed by workers. I mentioned how vans were simply full of papers which seemed to confirm one worker's thought that "it is a paper industry now".

In Switzerland I travelled to sites with the teams like I did in Britain, and within the SBB minibuses or vans I always noted one consistent feature: the lack of paperwork. Seats were always free; I never once had to move a folder, document, or loose bundles of paper before I sat down. When the driver put the vehicle into first gear and pulled away, not once did I have to instinctively catch a falling notepad, booklet or diary. When paperwork was to be completed in a van after work on site, the SBB worker completed two forms at most; the British worker completed much more before going home to do even more. Given these clear cut differences I had to ask about paperwork. One worker said:

...Those who have to make decisions do not have to go to the next in line, for that person to go to the next in line and to come to a final point of authority where there is permission for a decision. ... [this he thinks] counts for a low amount of paper (Fw: 33).

Interestingly, this respondent then said in incredulous tones:

In England you have very much papers... is it right that you have papers to write to say other papers have been written, and there are papers to say more papers are needed?! (Fw: 33).

Elsewhere I asked one man of a track renewal inspection team about paperwork: Do you have to complete a lot of forms when on site?

No, we don't, we are only a small office, we've a small [technical support] team, so it is not needed. For this we need confidence. I think in England you have a lot a paper work... you have a lot, yes? (Fw: 36).

It seems Britain's attachment to paperwork has gained a reputation beyond its own coast.

9.11 RCF THOUGHTS AND THE TIMING OF GRINDING

The research findings presented so far on SBB make no reference to manually completed rail-grinding. This should not be mistaken for a sign that forms of RCF do not exist on the SBB network.

On a rail there is some very light cracking which looks to me to be head checking. A UT operator points out that head checking is a problem, but this particular stretch of cracking is "*no problem – it is so light; one pass of the grinding train and it will be gone*".

As we are looking at the head checking I ask about the size of the problem – he replies: "*it is a problem for the whole of Europe*" – realising that I am hearing a remarkably similar statement to those I heard in Britain, I also hear a remarkably similar opinion as to why it is a problem now: "*who knows*". He then refers to the Pendolino (a specific type of train) services that are now operating and are quite new. He also mentions wheel profiles and tread, before adding a new possible reason: He thinks that it could possibly be because of the trend of powering trains by a locomotive at the end of a train – so that essentially the train is being pushed along the track instead of pulled. And regarding head checking's characteristics; he spoke of its unpredictability. He mentioned how: "*perhaps it grows fast, perhaps it grows slow*" (Fw: 31).

Consequently:

Gauge corner cracking can be considered as a recent phenomena: On the network of Swiss Federal Railways [gauge corner cracking has been] regularly detected for about 12 -15 years (Pfarrer: 2002).

In the same paper, the author then points out the now familiar and important role of experience, but in terms of RCF management:

The knowledge gathered on this subject [RCF], is based rather on experience than sustained by scientific findings. We realise that the phenomenon occurs almost everywhere, independently from the tonnage of the line. On lines with less traffic it just takes longer. Analysing deterioration patterns leads to a better understanding of the development of cracks and the adequate timing for rail renewal. With regular inspections by patrolmen – at least once every two weeks on main line track and ultrasonic testing – a close monitoring of crack development is assured (Pfarrer, 2002: Conference paper).

The close monitoring is characterised by close interaction between maintenance teams and technical support:

A tight feedback is seen as an essential part of [RCF management]. Every [RCF] defect leading to the replacement of a piece of rail is announced by form with all relevant data to Asset Management. Regular contact between the track teams, the Technical Support, and Asset Management are required to build up additional know-how which is given back to the staff through institutionalised training (Pfarrer, 2002: Conference paper).

On one occasion, I witness this interaction first hand during Fw: 36:

We are at a curve that is situated within the confines of a railway station. I notice immediately that there is a length of corrugation (a type of fault whereby the surface of the rail has successive, but minor dips, thus giving a rippled effect). However, it was interesting to see that attention by all parties was given to the wooden sleepers and ballast before the rails despite obvious rail surface problems.

Boris said: the condition of the sleepers is the principal concern here. Not so much with the metal sleepers elsewhere. This is because sleepers are not changed as much as rails. More priority is given to sleepers. The rail is eventually measured by a tool that records the effects of fatigue – and it is decided that the rail should be measured again within two years.

Sleepers, it seems, are indeed given priority over rail because of the length of time they are on the network compared to rails. Rails are changed quite frequently and this can be because of head checking, which it was pointed out to me, is a new problem:

"It is a big problem... a grand problem. When to start treating the problem that... that is difficult. You leave it for three months and the rail is finished". And the cause? "It is sometimes hard to find the right quality of rail, it is maybe that. And we have different traffic, different wheels. If we only had one type of traffic then maybe it would be easier... I think in France... the TGV... the TGV lines, I think they maybe do not have a problem".

From here I asked Boris about the role of grinding: *"It is too hard to do it by hand, and very, very costly to do it by hand... But, also, it is also very hard to pick the right time. When the cracking is very light, ideally we grind by the grinding train, this must be done just two weeks after the new rail is in place. If it is not done within 6 months of the new rail being in place, we have to change ... Not finding the right time creates a lot of maintenance work in a short time".*

The *hierarchy* of inspection discussed in this quote was defined by another worker more clearly:

Rails are subject to abrasions, fatigue, they are also easily changed. But sleepers, that is much more complicated. When you renew sleepers you have to remove rails, seats, bolts, pads, it is harder. It is a longer task than changing rail. With ballast we also have to remove sleepers, bolts, pads... [etc.]. Therefore we analyse the condition of the ballast closely, for when renewing that, we at the same time should renew everything. That is why we work this way (Int: 34).

Additionally, the problem of *when to grind* was referred to by another during my time on the track recording car. One of the men referred to the problem of shelling on fish-plated rail.

It's a great problem, even when grinding... It is not too helpful to grind because you have to go back... maybe two years later to do it again. So grinding, it is when it is done that makes it right. At the right time it can be helpful, but only then. If not then, it is not good (Fw: 34).

So what occurs when cracks are found in S&Cs?

An S&C costs four to five times more than rail. It has more functioning components; it is where traffic moves from one route to another. It has the potential to be the most hazardous part of a railway. ... When a crack appears on an S&C, we apply UIC [European Union of Railways] directions. There are three categories of cracks. The first category, we renew the S&C immediately, the last, we test often and suggest renewal within three to four months (Int: 34).

This passage connects with the words of others regarding the risk-management applied to S&Cs:

In the yard, there is a large area that is fenced off, in this *pen* I see a machine I recognise and which is used for removing lipping in Britain; I ask Joel what it is used for and when. "*It is used rarely*", he tells me. "*Sometimes, when the [S&Cs] have to be measured, [as they were earlier], lipping can cause a problems for [precision. Thus this machine is used to] move it, and for measurement to be done*". I then ask about grinding – do they hand grind the S&Cs at all? "*No*", is the short answer. He tells me the "*grinding train is used only when needed*", but it is "*impossible to use at [S&Cs] – grinding at [S&Cs] is not done*". I ask what maintenance occurs then if cracks or fissures are found on the S&C? "*They UT it, if there is an indication then it will be renewed*" – he tells me that "*this is the practice in Germany and France*", but he doesn't think that it is in Britain (Fw: 32).

10 CONCLUSION

10.1 INTRODUCTION

10.1.1 The lay-out of this chapter

In this final chapter, findings are dissected and analysed within the sociological framework illustrated in chapter one; the pattern of that chapter is replicated here. To start, I contrast my findings on the organisational structures of the British and Swiss industries. Then the two are evaluated against the organisational theories discussed in the opening chapter. The impact that the structures have on the actual work completed by maintainers is drawn out – how history and organisational change impact on skill levels, for instance, is explained. How rail maintenance knowledge is “packaged” and “distributed” by senior technicians to front-line workers is also of interest. Many of the key skills in the rail maintenance activities I described require tacit knowledge. Thus in the latter half of this chapter I point out the critical necessity of tacit knowledge for individual maintenance activities and, in doing so, I point out the problems that are created by the structural organisation of rail maintenance.

Knowledge, culture and context are indivisible and cannot be separated intellectually. Technological knowledge, like scientific knowledge, is not some sort of pure, objective matter that humans discover and absorb without manipulating. Technological knowledge, in other words, is a social construct in an entirely literal, non-pejorative sense: it is formed from a process which involves human decision-making, judgment, interpretation, and definitions. Moreover, these matters are impacted on by still wider issues. The aims and objectives of a group of people can affect how each member of the group, and the group itself, perceive data prior to deciding what aspects of it should become formulated into knowledge ready for distribution. In other words, the culture and context within which knowledge is constructed becomes a part of the knowledge itself. Ultimately then, knowledge is collectively constructed and is a social phenomenon. Knowledge is, indeed, social through and through (MacKenzie, 1990: 10). This thesis can be viewed as an addition to the body of work that justifies this opinion. The knowledge required for rail maintenance is socially constructed. Strengthening the argument is the focus on tacit

knowledge. Tacit knowledge underpins good rail maintenance: good rail maintenance relies on it. Tacit knowledge, we were told in chapter one (section 1.10 page 62), can only be transferred by inter-personal means. The argument is therefore this: if tacit knowledge for good rail maintenance is essential, then rail maintenance relies substantially on maintenance knowledge that is socially constructed.

10.1.2 The British industry past and present

In chapter three a brief account was given, depicting how BR's maintenance structure was organised. This is because it became clear to me in the early days of my research that I needed to complete some sort of socio-historic account of British railway maintenance. I reasoned that, if I was to know why actual, physical frontline railway maintenance procedures are the way they are *today* (when I observed them), I also had to know how they were shaped and completed in previous years and what impact any organisational change has indeed had. As Charles Perrow correctly points out:

Because interchange of structure and function goes on over time, a natural history of an organisation is needed: We cannot understand current crises or competencies without seeing how they were shaped (Perrow, 1972: 175).

It was during conversations with retired, semi-retired, and currently still working railway maintenance workers that I was able to gain an understanding of how railway maintenance was organised under the stewardship of BR. During these conversations I was given an insight into how training was conducted; how relevant skills were obtained; and how asset knowledge was developed, distributed, stored; how risk was managed; and how physical maintenance work was actually carried out by the manual worker. By gaining an understanding about these issues I was able to understand to a greater degree why railway maintenance, and what I saw of it, *was* the way it was when I saw it.

10.1.3 The regional baronies

For effective railway maintenance, and due to the very nature of the industry, railway organisations will always have to rely on geographically dispersed workers. Thus, as is common with other railway industries, BR's rail maintenance workers were

regionalised. It was argued that this set-up encouraged the development of “regional baronies” (Wolmar, 2001). Burns (1969), Burns and Stalker (1961) and March and Simon (1958) would perhaps postulate the existence of the “sub-group”. My findings suggest that so-called regional baronies did indeed exist and that the concept of the sub-group can be applied. Geographically dispersed groups of maintenance gangs tended to generate an affinity with their region: they were likely to develop sectional interests where their future security or betterment were matters of deep concern (Burns, 1969: 246). As the authors then point out, there is a clear potential for conflicting consequences of such sectional interests. However, in the railway industry, where rail maintenance work groups were sectioned off and worked in a specific region, it seems that, instead of generating only negative consequences, many maintenance teams tended to develop taken-for-granted cultures (Berger & Luckmann, 1966) of reliability and safety (Roberts, 1993; Sanne, 1999). This point was driven home to me when the men I spoke to referred directly to BR days. The idea of workers *belonging* to a region that housed its own working community emerged through my findings. Remember how the men spoke and the terms they used: workers spoke about a sense of “ownership” of an area of track; and when the men talked about BR they tended to do so with a degree of pride and with a passion that was perceptible and, remember, how being labelled a “railway man” had some prestige, whilst today there are now “contractors” or “cowboys” working on the network who are “not railway men” (Int: 08; Fw: 16; Int:18; Fw: 08; Int: 27; Int: 29; Fw: 07; Int: 14; Int: 13; Fw: 09). These aspects combined to create a workplace culture that enhanced a culture of safety, and what is more, the culture was encouraged by the uncomplicated access that railway workers had to “their” track (Fw: 08; Fw: 07; Int: 27a; Int: 03).

Sociologically speaking, new team members were socialised into work groups (Berger & Luckmann, 1966) and they were inclined to internalise the same commitments to work and to the area as the experienced railway men (Sagan, 1993; Barnes, 2000). This, in turn, saw regional gangs developing and training *their* workers *to their way of life* (Giddens, 1993), which Berger and Luckmann (1966) might argue, was underpinned and maintained by tacit social mechanisms. Components of culture such as language, custom, conventions, norms and beliefs underpinned and sustained

a group's own work methods which were guided by a regional chief (Cohen & Taylor, 1992). Recall the railway man who knew the name of each of the 447 men under his control in his area. Recall how workers had said they simply spoke to each other (Int: 14; Fw: 02) and that, if you never knew how to do something, you would ask someone, for there was always some who would know (Int: 18). These rather incidental, seemingly trivial and mundane, taken-for-granted (Berger & Luckmann, 1966) aspects of working life were instead hugely important as they let feelings of ownership and pride generate within groups. Team members tended to develop a common orientation to the task (Barnes, 2000; Goffman, 1959, Sanne, 1999). The teams generated tacit understandings among members (Berger & Luckmann, 1966) which would encourage mutual support and allow for the transmission of experience-based tacit knowledge.

10.1.4 SBB and BR – the similarities

By taking a step back in history to look at how railway maintenance was organised prior to privatisation in Britain, we see some similarities with the set-up of railway maintenance at SBB of Switzerland, as I experienced it during the research period in this country.

The first thing to note is how the Swiss nation-wide network is broken down into 23 small regional sections. Within each of the 23 regions there are several teams that have clear-cut tasks – and as one would expect, there are teams with identical tasks to some of these teams in Britain – there is for instance, a three-man ultrasonic testing team. A strong sense of autonomy that characterised BR's regional baronies, it appears, also characterise SBB teams. Recall for instance, the likely reason as to why it had been decided to cut (just slightly) the amount of visual inspections to be completed by an SBB worker on a length of line in a region:

Perhaps in their district they have decided that walks on some lines can be reduced. I would think that decision will be because of traffic. Freight has reduced... walking should refer to the rate of traffic, tonnage... if tonnage increases, walking must increase. If the walking on some lines has gone down, traffic has reduced (Int: 34).

Such decentralised decision-making by workers within each of the individual 23 districts is typical. The idea that the “man in the district has the responsibility” (Int: 30), is borne out through a considerable degree of confidence and trust, which one might argue could be described as a culture of reliability – as one senior SBB engineer told me: “We train people, we give them the required competencies. We have delegated a lot of competencies to the front” (Int: 34). This philosophy was explained to me quite plainly in a discussion with a senior member of SBB’s ultrasonic testing community. During a discussion about risk management and the “location” of authority within the decision-making process if a serious fault is found on a rail, I was told: “When he (the team member who found the fault) says no trains, I trust him, he means no trains! He has the experience” (Int: 33a).

10.2 CREATING A CULTURE OF RELIABILITY

10.2.1 The permanent way and socialisation (the SBB example)

During another phase of research I was given an insight into how SBB’s culture of reliability might be nurtured. The facilities at the headquarters and base of one of the 23 regions that I visited, I was told, were similar in make-up to those of the other 22, and one of the first things I noted was the quality of the facilities. There was a communal area where workers could relax together, and there were facilities for them to prepare food and to eat together if they so wished. The building was spacious, bright, clean and comfortable. Creating a comfortable environment for workers to prepare for work and to rest after work was seen as an important “part” of railway maintenance – people have to enjoy coming to work, it helps motivation (Fw: 32). There was a marked difference between the places that workers met up to prepare for work in Britain compared to Switzerland. In Britain, workers tended to prepare for work in grubby “portakabins” or small huts and rooms cluttered with items such as dirty kettles and broken machinery, such as faulty walking sticks (Fw: 01).

The SBB organisational set-up had a positive impact on some workers. One told me quite plainly that SBB was a good company (Fw: 30), whilst another told me of his pride working for SBB and that he is embarrassed when things go wrong and he is seen wearing an SBB logo in public (Fw: 33). The organisational make-up also helps

to nurture a sense of belonging among workers – this was demonstrated to me whilst watching work on the track recording car. Whilst aboard this train I noted how the personnel aboard changed every so often. The explanation was quite simple – when the car crossed a regional border workers changed. Those who left the car took with them “their” paper work that documented “their” findings – that is, they took with them information about “their” region, and the workers that replaced them, worked with “their” documents about “their” region. Again it was the language that was used that highlighted this – recall this defining quote: “Teams ... they take a special pride in their rail region” (Int: 33a).

Training mechanisms also aided the development and “maintenance” - in Berger and Luckmann’s, (1966) use of the term - of a sense of ownership. Workers at SBB have to complete three years of structured training, which involves the new employee being fixed up with a team in one of the regions. Their progress is charted before they are tested and qualified as a track worker (Int: 34). In this way the worker also picks up valuable skills that can only be learnt on the track. This often involves watching and then emulating the activities of experienced track workers. On one occasion – the measurement of an S&C’s gauge (section 9.7.2 page 279) – it was noticeable how the trainee was guided on how to complete paperwork, yet he was also made aware of the subtle noises to listen for which might indicate a problem. On another notable occasion (section 9.8.2 page 294) where I witnessed one worker being trained, I noted how he was again guided on site by experienced workers. Everything he did from paperwork to the actual assessment process of permanent way assets was scrutinised by his experienced colleagues.

Experience, and the process of gaining experience, at SBB, is a highly valued commodity (fig. 9.6 page 266) that comes in many forms, some of which can be quite unexpected. For instance there is the worker who had come to know how dripping should “sound” in a tunnel, and what size damp patches on the walls were allowed to be (Fw: 30). This is the type of tacit knowledge that the bottom-up and top-down plans rely on, and exercise extensively. SBB and BR place[d] a considerable amount of importance on the role of experience in permanent way maintenance. The words:

“Experience is more important than training” (Int: 33), were uttered by an SBB worker but could easily have been spoken by a BR worker. Despite this, however, there is a marked difference between the outlook on training in SBB and how it was formally structured in BR. In SBB a clear cut system is in place; during the time of BR, training was underpinned by a subtle learning process which was markedly different.

10.2.2 The permanent way and socialisation (the BR example)

Many of the railway workers in Britain told me that during the time of BR there was little to no official training for tasks such as track inspection, instead it was commonly accepted that new recruits to regions simply watched-and-learnt. What could be “labelled” as training for track inspection was not done in a classroom (Fw: 09). Instead, forms of training were characterised by norms that were habitually and tacitly activated. There was a rather *laissez-faire* approach to precise learning strategies. On the face of it, this form of training had assumed a rather deceptive *taken-for-granted* pretence (Berger & Luckmann, 1966). I come to this conclusion because of the way the men described learning strategies; they tended to recall it in a rather matter-of-fact tone.

Basically there was no training, it was passed on; it was all stuff you picked up and you progressed that way (Int: 13).

There was no specific training, no formal training for track inspection, it was on the job. The track patroller would walk the track one, two, maybe three times a week, if you saw something you would report it to your engineer. Knowledge was passed on like that (Int: 18).

Strands of Kunda’s research (1992) may be recalled here. Remember how the manager of the engineering firm he interviewed spoke about the workers and the organisation: he said, “They are committed there is no doubt”; “That formal structure tells you nothing”; “The idea is to educate people without them knowing it”. Clearly there was an important role for what Berger and Luckmann (1966) would refer to as “tacit learning”. The socialisation process that was in place at the engineering firm, in Kunda’s (1992) text was clearly important, as was the socialisation process that was

operated within the regional baronies. If we draw a link with the “regional barony” structure and the high reliability research work of Roberts (1993) we will see the importance of this form of socialisation in action. The Berkeley theorists found that the successful organisations created and maintained informal organisational structures that varied and were adapted to the problems at hand. This is a key requirement for the railway industry’s regional teams because of the nature of the permanent way and the varied environmental influences.

From the start of my research it became clear to me that the term “permanent way” is a misnomer. The track moves this way and that ever so slightly when a train passes over it – when it moves in the vertical direction, it is called “voiding” (Fw: 07). A section of track can develop idiosyncratic characteristics, and because of this even the smallest section of the permanent way has been described as having its own “existing memory”. The permanent way is likely to exhibit problems peculiar to areas: there can be “local” problem spots due to the numerous variables interacting at the wheel / rail interface (see chapter three, section 3.1.2 page 87). During interviews, respondents often spoke about different areas being prone to different problems. Some sections are known to suffer from flooding; others are prone to “wet-beds”; some lines are more likely to exhibit a specific type of rail fault more than others. Consequently experienced workers “knew” what areas should be monitored more closely than others (Int: 01; Int: 27; Int: 27a; Fw: 01). It is precisely because of the nature of the permanent way therefore that experienced regionally based teams are a necessity. It is exactly this type of information that new recruits “pick-up” on the track through socialisation and which lets them gain experience. As a result of informal training mechanisms, workers get to know that some sections of the permanent way required visual inspections that are more frequent than official instructions stated (Int: 23). There was, as Roberts (1993) might argue, an approach to formal regulations and codes that showed workers using their own discretion and judgement.

This form of training (or socialisation) was vital as it often involved and encouraged the transmission of tacit knowledge and know-how. Such knowledge can only be

picked up by emulation – it cannot be transferred entirely by impersonal means because the skills required have not, or cannot be codified (MacKenzie, 1996a: 215). It comes as no surprise, therefore, that critical, regionally-based knowledge of problem spots, common rail faults, and other localised permanent way weaknesses and other asset knowledge were carried *in* the workers themselves, as the Rail Regulator acknowledged: “too much essential knowledge [is] locked up in the heads of people who had left the industry” (Winsor, 2001: Conference paper). The words of Tom Burns (cited in Collins, 1982: 45), seem particularly apt: “Knowledge consists of the ability to do something ... Knowledge is the property of people rather than documents”. As a consequence, this ultimately meant that work planning within British Rail was based on a work bank with significant local discretion (Edmonds, 2000) and with this in mind, the metaphor of “regional barony” seems perfectly apt also.

The training structures operated by SBB and by BR are different, yet, ironically, they showe(d) the same aim – instilling practical experience and knowledge within the new worker. Nevertheless, training methods and all other aspects of the industry were radically re-structured during the privatisation process of the early 1990s.

10.2.3 Privatisation and Hatfield

Though not the reason for privatisation, the social causes of the Clapham Junction disaster of 1988 (see chapter three: section 3.2.1 page 95) showed how some aspects of the BR set-up were inefficient and in need of an overhaul. BR’s operating inconsistencies were handled during the Organising for Quality project when steps were taken to remove managerial and track work “deadwood”. The Safety and Standards Directorate also desired more control from a central base; and as part of this, thousands of working-procedures (instructions) were introduced. It was the Hatfield disaster in October, 2000 that harshly exposed the weaknesses in the organisational system that had been created unintentionally by the privatisation process – recall the bulleted timeframe of events leading to the disaster in chapter three (section 3.1.2 page 92) and how this suggests that the accident was down to “systemic, structural reasons” (Hutter, 2001: 298).

The restructuring of the industry transformed the BR maintenance system – this was intended, but restructuring inadvertently threw away strengths – namely the know-how that was locked up in the heads of those track workers who left the industry. A large percentage of a valuable, knowledgeable, and experienced workforce of BR that tended to develop pride in their workmanship had been discarded. One quote summed up the point: “The problem with privatisation was, there was a big loss of expertise, and with privatisation you had all these contractors coming in, and, they never had the experience. So, there is a big lack of experience” (Int: 27a).

Prior to the Hatfield derailment there had already been much concern within and outside the industry that railway maintenance skill levels had been dropping, and that this was having a severe impact on safety levels. Therefore, when the accident happened, this argument was again brought forth, but this time it gathered momentum because of the actual reaction of the industry to the crash itself. The reaction highlighted varying and inconsistent levels of specific maintenance skills and methods across the national network – none more so than in the skills required for competent visual inspection.

Industry leaders had to respond to Hatfield immediately. The nature of the response was influenced by a fear that another crash caused by the same type of rail fault could soon be repeated somewhere on the network’s 20,000 miles of track: hundreds of miles of track were walked in the following days and weeks as visual inspectors desperately tried to find instances of a problem called “RCF” before it caused another catastrophic derailment. During these days many false RCF sites were recorded by visual inspectors because they did not possess adequate skills, knowledge (including tacit knowledge) or experience to know what RCF was. It stands to reason that if a large percentage of visual inspectors did not know what they were looking for *after* the crash they would not have known what RCF was or how to look for it *prior* to the crash. The argument that skill levels, and therefore safety levels, were questionable thus gathers momentum. However, Reason (1997) reminds us that sharp-end human failures (in this case, the failure to note genuine RCF) could be a consequence of more deep-rooted reasons rather than the original cause of industrial accidents. In this case

we could argue that the process of organisational change from a nationally-owned single unit to a privatised and compartmentalised industry, which indeed was based on plausible commercial arguments, was the deep-rooted cause⁹¹. For, as Reason reminds us: “no group of managers can foresee all future ramifications of their current decisions” (1997: 12). This argument is developed now.

10.2.4 Hatfield, decision-taking and language

Decision-making by senior managers can indeed cause unforeseen and detrimental ramifications and a striking example of this can be seen in the industry when leaders started to use the term “RCF”. Industry chiefs regularly used the term in the aftermath of the crash, but still some months prior to the release of an instruction - PWSI4 (Railtrack, 2001e) - that would eventually define it. At this point we should remember the point Nelkin (1985: 25) made: “As action flows from the definition, the way a problem is framed has an important bearing on what is or is not done about it” – this sentiment certainly has parallels with the “RCF” management problem.

I noted there was no precise definition of RCF for permanent way workers some twenty years ago, despite there being at least one preliminary study into the problem in 1974 (see chapter five, section 5.5.1 page 142), yet today it is common parlance in railway maintenance, due largely to the Hatfield disaster. This meant that in the days just after the Hatfield derailment, when hundreds of workers were walking the track, the competence level of the inexperienced visual inspectors was not the only problem. Many experienced railway men who had been in the industry for years prior to privatisation were also puzzled. One railway worker who had been in the industry for many years gave a graphic account of how he perceived this period of time:

It was pure panic, we walked hundreds of miles of track being told to look for RCF, and we're asking: What's RCF? What's gauge corner cracking? So people just didn't know what they were looking for and noted everything. Then the first time I saw it, I was out walking with a guy from

⁹¹ I am not saying that the cause of the crash was because the industry changed to a privatised one – what I am saying is that the cause of the crash was due to the actual process of organisational change.

Railtrack and he pointed it out to me and told me: “That’s RCF”. I thought, “that’s shelling”!
I’ve repaired that thousands of times! (Int: 28).

Structural change in Britain disrupted (and in some areas eradicated) important forms of knowledge, but it also disrupted important, corresponding language codes which had been used for effective rail maintenance. This situation was then compounded as organisation-leaders implemented measures by labelling the problem RCF, which only confused the experienced and inexperienced worker alike. As Downes and Rock (1982) and Scheff (1966) would point out: there are abundant labels and terms available to those who witness (technical) deviation and, despite such labels apparently embodying general and seemingly objective ideas, there is often some scope for negotiation.

10.3 UNRULY TECHNOLOGY AND INVENTING RAIL FAULTS

10.3.1 Technology and opinions

At this juncture I need to draw further attention to the “comprehension” of the technical artefact that is the wheel / rail interface. It does not do to say that RCF has always been at the current level and that privatisation removed skills that would have identified it and would have thus prevented the Hatfield disaster. Indeed, as was pointed out, the problematic rail at Hatfield was known about: it was organisation-based delays that prevented the rail from being renewed (section 3.1.2 page 92). Nevertheless, the underlying point of this section is actually demonstrated in the form of two contrasting quotes that are referring to the same subject. Of RCF’s “existence” one railway worker said “It’s been around for years” (Int: 21) whilst another said “it’s a new phenomenon” (Fw: 07). Both of these quotes are, paradoxically, correct.

Firstly, the idea that “It’s been around for years” is defensible. We need look no further than to the work of the locomotive pioneers (see chapter four, section 4.1.2 page 110) to see that forms of what could have been called RCF came into existence the very moment an iron wheel was placed on an iron rail: frequent contacts between the wheel and the rail, Richard Trevithick quickly discovered, diminished the fitness-for-purpose of both. Some years later, in the 1830s, and in response to the problems of

the wheel / rail interface, Mr. Nicholas Wood conducted numerous experiments on friction resistance. His findings suggested that a succinct account of the laws that govern friction and wear was hard to come by. Even early on then, it seems Trevithick had invented a mode of transport that was adopted widely, despite being built upon a problem interface at its very heart (Arthur, 1999).

Now despite this, it can be said that the actual *increase* in the prevalence of RCF defects can be considered as “a new phenomenon” because of a perpetual accretion of technical details (MacKenzie & Wajcman, 1985) and financial changes. A senior member of the Wheel / Rail Interface Systems Authority suggested that since privatisation, traffic had become heavier and journeys have increased (Clementson, 2002b: Conference paper) and that these changes had an impact on the contact spot where the wheel meets the rail and that RCF has increased as a consequence. Technicians at a rail producing plant’s testing laboratory concur – “There has been a significant change in the weight of the vehicles, in the speed of the vehicles. That has to have an effect” (Int: 23). What was also important was that the same speaker then referred to the decreased level of financial investment in railway maintenance, and that this too had had an effect on RCF’s increased prevalence and higher risk status (see chapter three, section 3.4.1 page 102). Nevertheless, others referred to the impact of the aforementioned technical changes and their relationship with RCF occurrences. For instance, one said: “But it is a dated system and the imbalance is using vehicles with higher tractive and braking forces on it. There’s been an optimisation of vehicles, but not with rails” (Int: 25).

Similarly, another pointed out that the chemical composition of rails has not changed much (Int: 22). This point was further agreed upon by another (Int: 27a). Now the idea that the comments “it’s been around for years” and “it’s a new phenomenon” – are both correct can be explained with reference to Wynne’s work (1988), Barnes and Edge’s work (1982), and MacKenzie’s work (1996b). The explanation also gives a little more insight as to why experienced and inexperienced workers alike were puzzled in the days following the Hatfield disaster. Firstly I will link a quote of

Wynne's with the matter at hand, the text in [square] brackets having been added by me:

During technological evolution [for our case – technological evolution has come about in numerous ways. An increase in traffic volume and an increase in traffic weight are technological changes just as much as technical changes in speed, braking and traction forces. Add these changes to slight changes in the chemical make up of the rail and we conceivably have a series of small technological evolutions at the wheel / rail interface over a period of time] relevant practices [rail maintenance procedures] are re-capitulated into an up-dated statement of formal rules - for example when new codes of practice [PWSI4] are issued by a regulatory body [Railtrack] (Wynne, 1988: 153).

Ultimately this means that some types of rail failure previously perceived as less hazardous have now come to be seen as a bona fide threat to safe rail travel. The technological changes mentioned above, we can presume, created an unexpected effect (Wynne, 1988) – and that effect has been a rise in the occurrence of a defect which would become commonly known as “RCF”. This meant that railway industry leaders (when this type of defect became more frequent) initially had to interpret this type of rail failure, and they had to define it. This had two notable outcomes, the first being the issuing of the PWSI4, and secondly, the use of a specific type of rail was halted, namely, mill heat treated rail known as grade 260 (see chapter five, section 5.5.1 page 146).

Helping to explain these responsive actions is Barnes and Edge's (1982: 150) thought that “Existing knowledge is always liable to prove insufficient: additional unexpected features invariably appear in every new artefact or material process, throwing new difficulties in the path of advance”. Quite similarly, the “RCF example” shows how definitions of rail failures and defects are fluid and subject to incremental change, and the interpretation of associated new risks is, of course, entirely dependent upon the community (railway industry leaders) that decides “what similarities matter and what differences do not in technological testing” (MacKenzie, 1996b: 255). So, faced with the “new” higher risk of an “old” problem, the community of railway industry leaders decided to communicate their interpretations and definitions to the front-line working community through PWSI4 (Railtrack, 2001e) and RT/PWG/001 (Railtrack, 2001a).

10.3.2 Wheels and rails: the meeting point

However, there is another important matter of concern here. Evidently the management of *both* sides of the interface is critical. Changes in the rail's make-up and changes in the technical make-up of vehicles travelling upon it are of clear importance. Thus, it is how representatives of the two sides interact that has also proven interesting in this thesis.

Firstly, prior to privatisation it was pointed out to me how (in Britain) there was, for instance an industry newspaper (Fw: 20), which was often used as a source to find out what was *going on* in the industry regarding research and development. Now linked to this is a conversation I had with another (Int: 05) who was referring to wheel profiles whilst talking about RCF and its potential causes. He referred to BR's research and development base at Derby, and he mentioned how the company had its own rolling stock engineers who dealt with wheel profiles. But, during privatisation, this part of the organisation was sold off, and a consequence, he suggested, was a lack of knowledge about what is going on in the industry. And by way of example, we need only look to his answer when I asked him about wheel profiles: From "an Italian company", he said vaguely and hesitantly. There are further connections to be made on this theme from chapter five. Recall how rail management computer programmes would require "industry-wide collaboration" (Ms Wasserman's "Wheel-Chex" presentation, chapter four, section 4.2.3 page 119) and remember how a speaker from WRISA stated that there was a need for the industry to get "in balance with itself", and that technical changes on one side of the interface, concerning vehicles, could be harming the rail (Clementson, 2002b: Conference paper).

Overall, it would appear that the two key players on either side of the interface (vehicle operating companies and railway maintainers) in Britain, arguably since privatisation, do not communicate sufficiently with each other – one interviewee (Int: 06) suggested that there was actually "zero" communication between the two. Nevertheless, it was also noted that it was Railtrack's job to be the intermediary between the two, yet how the company went about this task was questionable (Int: 22; Int: 02; Int: 06). The quality of communication and interaction between railway

maintainers and train operating companies (TOCs) was probably demonstrated best during the discussion on “possessions” (see chapter five, section 5.6.2 page 148). Interviewees 3; 5; 7; and 27 each explained the difficulties due to the conflicts in aims when juggling time for rail maintenance whilst ensuring minimal disruption for traffic. This issue was perhaps explained best when one respondent said: “The relationship with the TOCs is moving towards a better relationship... but it is still really us and them... it’s all very political, they’ve got share holders... but it is getting there, it’s moving to a formal process” (Int: 29). Echoes of the work of Burns (1969), Burns and Stalker’ (1961), and Clegg’s (1990) work can be noted. It would appear that the industry has developed a mechanistic / Fordist mode of thinking – TOCs are interested only in their affairs and maintainers likewise: the two are differentiated and segmented. Yet the nature of the industry means it has to respond to technical problems that may be unexpected, thus requiring it to work, ideally, to principles associated with postmodern organisations (Clegg, 1990), i.e., organic / flexible organisational systems (Tomaneniy, 1994). Such principles seem to characterise SBB’s organisation regarding this matter.

SBB has a specific organisational structure that has recently been implemented with the aim of mediating between traffic operators and railway workers - the organisational form appears to bear post-Fordist / organic-system characteristics (Grint, 1998). The process involves the role of the integrated maintenance manager - IMM (Int: 31a). The IMM role is to bring together the two parties either side of the interface (see chapter nine, section 9.3.2 page 262). Railway maintainers and traffic operators, we were shown, have a sense of responsibility and understanding of what is essentially the main task of the other. Train service operators are involved in planning railway maintenance possessions, and railway maintainers are informed about the needs of traffic operators. Railway maintainers, for instance, know what the key busy routes are and how much work can be planned at any one time, and train operators know that rails must be maintained and will change timetables (only very slightly) in accordance (Fw: 33). In an other way, the problems that railway maintainers and train operators experience are typically technically complex and can rarely be broken down into precise steps, meaning the organisation would not function effectively if the workforce was differentiated and segmented: as Grint (1998: 284) suggested:

“Flexible technology with an inflexible workforce does not lead to flexible production.” The planning of railway maintenance on the SBB network is done in collaboration by the railway maintainers and traffic operators. Both, through flexible / organic organisational design, are keenly aware of each other’s aims and both are responsible for railway maintenance.

10.4 TACIT KNOWLEDGE AND RAILWAY MAINTENANCE

10.4.1 The efficacy of the written rule, or railway engineering as a bureaucratic profession

After the Hatfield disaster it was made clear that, in Britain, some of the expertise to deal with RCF, or what was known as “shelling” or “flaking”, had been lost. During fieldwork I gained an understanding of the skills that are required for competent RCF management. RCF inspection is often done at night and a keen, trained eye that can pick up tiny cracks in yards of rail is a critical necessity, yet learning “how to look” and knowing “what to see”, and “what to assess”, and in many cases, “what to feel for” on the rail surface is a very difficult thing to learn and to put into words. Some of those I spoke to agreed (Int: 08; Int: 21; Int: 23; Int: 02; Fw: 01: Int: 28; see also Wolmar 2001: 3).

As the British national network nearly ground to a halt as numerous unnecessary speed restrictions were imposed after the false reports of RCF, a stark example of the difficulty in diagnosing genuine RCF was demonstrated. Clearly the required skills were not available nationwide and thus there was a need to standardise the work practices and to virtually start anew. Consequently, industry leaders issued a specific instruction for the management of RCF (PWSI4, Railtrack, 2001e) which delivered definitions to the workforce. However, understanding the actual language of rules and procedures requires the ability to “understand” from an experiential base (Wittgenstein, cited in Kripke, 1982); and therein was another problem. Due to structural change some areas of the British network were not equipped with the resources to understand the procedures.

We can understand why workers were confused if we utilise sociological concepts. Organisational chiefs had tried to implement a new language for a problem immediately. They issued more instructions – this time using (new) terms to codify, construct and define a technical problem. During the “Organising for Quality” project, and since, several thousand documents have been released⁹². The imposition of these documents can be connected to the work of Daniel Bell (1974: 19). He noted that modern industries were increasingly turning to theoretical knowledge as a way of controlling and organising work. Bell said that, theoretical knowledge was typically transmitted to workers through “codification ... into abstract systems of symbols”. However, critical requisites needed for competent understanding of these symbols, terms and definitions (Nelkin, 1985) were missing. New terms need to be understood by the relevant communities (Mannheim, 1982; Berger & Luckmann, 1966) and such understanding and knowledge development, including the acquisition of tacit knowledge, are typically transmitted to new members during a period of socialisation by those already embedded into the relevant culture (Faulkner et al, 1997; Goffman, 1959; Barnes, 2000; Collins, 1982; MacKenzie, 1996a). New members learn about their role and the relevant vocabulary during a process where they are exposed and sensitised to a strong embedded culture. For the case in hand, the relevant culture had been broken and the resources required to understand and interpret instructions were diminished by differing degrees across the network, due to organisational restructuring.

Implementing a new language, new instructions, and new definitions by the medium of paperwork was arguably always going to be difficult for effective RCF inspection and risk management. Thus we can concur with the fundamental thought of the high reliability theorists that industrial catastrophes (such as the Hatfield derailment) are

⁹² Of specific interest to us has been the series of PWSI4s, the RCF best practice guide (RT/PWG/001, Railtrack, 2001a), known colloquially in the industry as “the blue book”, the additional ultrasonic testing instructions – (Railtrack, 1998b) namely the U14 and the instructions for “the Sperry”, and finally the document for manual rail grinding (RT/PWG/002, Railtrack, 2001b) – sometimes referred to as “the green book”.

consequences of a breakdown in social processes and comprehension (Roberts and Wieck, cited in Sanne, 1999: 24).

Harry Braverman (1974) might suggest that the problems experienced within the industry after the Hatfield disaster were exacerbated by a clear-cut separation between “thinking” about rail maintenance and “doing” rail maintenance. By issuing the likes of the Blue Book (RT/PWG/001, Railtrack, 2001a) and the PWSI4s, industry leaders were promoting the primacy of formal rules and procedures, and they were intending to standardise the activities of the rail maintenance workforce – and because of this it is perfectly reasonable to suggest that rail maintenance workers (particularly experienced workers) lost a certain degree of control over their work⁹³.

My findings resemble those of Vaughan’s (1996) analysis of organisational change at NASA. To start, Vaughan noted that organisational change at the space agency led to the use of many more private contractors. Communication between the many facets of the space agency was often completed through paperwork and formal procedures (Vaughan, 1996). At NASA this often meant that the demands of bureaucratic standardisation did not accommodate (or could not allow) an engineer’s judgement call to inform the decision-making process. The form of routinisation at NASA demanded clear-cut answers to decision-making choices – there was no leeway that could accommodate an engineer’s or a technician’s “hunch” that something could still go wrong despite all the safety checks aligning with bureaucratic protocol. By keeping in mind this idea and by recalling several issues from my research, it will be

⁹³ Interestingly, and perhaps suitable for further socio-linguistic research in itself, is that “RCF” is a commonly used term in wider engineering disciplines. A search for the term in scientific and technological journals will show that the term is often used in titles. Yet in the railway industry, it can be suggested, the actual use of the term differs according to the worker’s situation – my research suggests that there is a linguistic split between the parlance of track workers and scientists. For instance, it was noted how RCF was a new term to much of the permanent way based-workforce, yet the term RCF we know has been discussed in papers from 1974 (see chapter five). Additionally, one industry scientist for instance hinted at this split when he said: “My perception of the industry was that it was extremely difficult to get to understand the practical situation of the railway / wheel interface because effectively the guys running the railways said you guys go and do what the hell you like in the laboratories leave us to run the railways, don’t come and interfere” (Int: 23).

argued that railway engineering in Britain has assumed similar hallmarks of a bureaucratic profession.

10.4.2 “Engineers are now administrators” (Fw:09); “It’s a paper industry now” (Fw: 12)

When the “Organising for Quality” project was put into action, streamlining the industry was a key aim, as was regaining more centralised control. This had an additional affect on the type of work that railway engineers were now asked to complete: “The whole concept of engineers has changed... engineers are now administrators” (Fw: 09).

The amount of paperwork that employees are required to complete was illustrated comprehensively in chapter five (section 5.3.3, page 134). At least 13 different administrative steps are required to ensure one defect is “managed” in the proper manner from initial discovery, to re-inspection, to responsive action, and to final re-inspection. Quite clearly there was a “laid down process [which was] quite a complex [and] quite a strict system” (Int: 02). Perhaps the most telling comment about the gulf of paper work to be completed by British workers, however, came in the form of a question to me which was posed by a Swiss railway worker. With sincerity, he asked me: “In England you have very much papers... is it right that you have papers to write to say other papers have been written, and there are papers to say more papers are needed?!” (Fw: 33).

To be fair, the administrative process in Britain can be seen as the continuation of a trend that has come to characterise modern industry *in toto* – the imposition of rules and guidelines (Hales et al, 1988). Michel Foucault’s work (1970) on the growth of organised knowledge may be recalled here. His idea that administrative mechanisms are becoming increasingly salient in modern society (for our case that includes workplaces), and that they have a “controlling” influence on its members (i.e., workers) can be linked with this particular study: the amount of paperwork circulated in the industry has created particular problems for some workers. There was a degree of pressure on the worker to comply with the documents. As interviewee: 06 pointed

out: “we are duty bound” to follow the procedures, and if you “break the rules your arse is out the window” (Fw: 07). This meant that the paperwork affected track workers considerably⁹⁴. One of the abiding memories I have of my time with track workers were those periods of time I spent travelling with them to sites. Apart from being a moment for me to chat casually and informally with them about their work, it also gave me a sharp insight into the amount of paperwork that is circulated in the industry.

The insides of the vans I travelled in (in Britain), I imagined, resembled the aftermath of an explosion at a small stationer’s outlet: there was quite literally paper everywhere; binders everywhere; pens everywhere; documents of varying size everywhere – the scene within the vans of the SBB workers, I observed, was almost the complete opposite⁹⁵. Despite the pragmatic nature of the problems with a lot of

⁹⁴ Problems with following paper work became evident when on site. Finding a defect according to the last inspector’s mileage could prove difficult for several reasons. There could be false reports from the ultrasonic testing unit – and paint is often sprayed at the wrong area (Int: 27b; Int: 04; Fw: 02). If an inspector marked out the location of the defect by striding out the yardage, his actual height affected the distance he walked (Int: 02). If the defect was near a station, the mileage posts when compared to a measuring stick were different because mileage posts are not positioned at stations (Fw: 07). And the problems of sites within sites if the defect is at an S&C were noted (Fw: 02 & 11). These practical problems add to pressure – time to get work completed during a possession is at a premium – not being able to find a defect promptly cuts into the time. Thus, completing paperwork on a shift and during a possession is typically not done. The ordering of work (i.e. listing what sites to visit in order whilst accounting for location so as to not double back on yourself) is done before work (Fw: 02), and the paper work required to detail the findings of the shift is often done at home and faxed into the office (Fw: 12).

⁹⁵ Some of the documents and papers included the latest PWSI4. Other booklets detailed rail faults and gave photographic examples (The Rail Failure Handbook, for instance, or the “Blue Book”, Railtrack, 2001a). Some papers listed mobile phone numbers of signalmen, colleagues, and PICOPS. Others papers listed the work that was due for the week. These papers told the worker what type of inspection should be completed at the sites – visual or ultrasonic; other papers noted the date of the last inspection, the type of fault, the severity of the fault, the location and mileage, and often there was space for “additional comments”. This space often created problems however. In the first part of this chapter I spoke about language and the problems of definition throughout the workforce. The section for “additional comments” could be confusing in itself because “even people’s terminology can be different” as said interviewee: 05, and on the same topic another said: “The information we put in, it’s doesn’t come back. I try to put in as much information I can under comments – RCF, longest crack length, has come back at [location name] on switch blade, or stock rail if is that, at [S&C number]. We give them that information, but when it comes back to us [stating the inspection frequency that the fault requires], it will say mileage, location and rail, but, it won’t tell you if it’s the stock rail or the blade... means we have to check both, or the length of the longest crack... I know the area and can remember

papers, there are further problems connected with the actual technical content of instructions which is now discussed.

10.4.3 Shall do in accordance (Int: 03)

This thesis has, in parts, been about the management and utilisation of tacit knowledge required for rail maintenance. It was shown earlier how the workers of the regional baronies acquired it, and it has been shown how the PWSI4 and other documents struggle to account for it – tacit knowledge cannot be formulated explicitly. This means problems may arise when a technological organisation demands strict compliance with technical procedures for so called “best practice”, which could essentially be underpinned by tacit knowledge.

Robert Merton told us that the existence of numerous bureaucratic procedures can exert a “constant pressure upon the official to be methodical, prudent and disciplined” (1957: 198). Such pressure can often displace the organisation’s goals: instead of adhering to rules to *reach* a goal, the very idea of adhering to rules becomes *the* goal. This, Merton argues, means that organisations can develop rigidities and can become unable to adjust to contingencies – conformance with disciplined procedures, whatever the situation, becomes an embedded way of life for the bureaucrat (1957). Merton’s ideas were applied in Hirschhorn’s (1993) analysis of working procedures at Ocean Reactor. Interpreting and then following the written word, Ocean’s workers found, was difficult. Tacit knowledge was often required for good practice, thus ambiguities and contradictions were commonly found in the instructions which left the worker in a precarious situation. They often felt accountable for mistakes and feared being personally fined or punished, thus to protect themselves they would often follow bad procedures and management processes “unthinkingly” or correct them “carelessly” (Hirschhorn, 1993).

the majority, but I can’t remember each and every fault I test, I test hundreds every week!... I don’t know if it’s a problem with the software package... but we get little feedback” (FW: 02).

I found that railway workers encountered similar problems to Ocean Reactor workers – how to follow / interpret the PWSI4, how to conform to procedures (say measuring a crack) and, finally, how to manage risk (crack categorisation). All are instances where difficulties were encountered. One respondent, in his terms, suggests that workers can treat the documents as “black and white” and end it there, or they can involve “human interpretation” and an “analytical process” (Int: 23). My research is littered with examples of workers using their own ad hoc interpretation; often it was used to compensate for documentation discrepancies.

10.5 TACIT KNOWLEDGE AND VISUAL INSPECTION

10.5.1 Decision-making – an analytical process

In chapter six (section 6.1.1 page 152) some of the technical content of the PWSI4 that visual inspectors have to follow has been detailed. The sub-types of RCF are detailed and it is illustrated where they occur on the rail head. The document also shows how the individual cracks are to be measured: workers have to take into account the entire shape of the crack, noting all its branches, and each crack in a section has to be labelled on the web of the rail. This is difficult: “it can all get confusing” (Int: 01).

It was also pointed out that actually finding a crack could depend on luck (Fw: 02) and furthermore, to be sure it was genuine RCF you really had to be on your hands and knees touching the rail whilst operating tactile skills (feeling for serrated edge in the shadows) - something that was not practical during normal working conditions (Int: 03). I also noted that some workers used a measuring device and others did not. The reason for this difference comes down to group-based or individual interpretation and judgment. Many of the workers I spoke to and observed in their work (Fw: 02; Ints: 04; 07; 03; 08; 06; 27a; 21; 02; 01 – see chapter. 6 section: How long is a crack? Page 158) agreed that visual inspection of RCF required a *guess-timation* of the effect of numerous variables that were presumed to be of importance during the moment of the actual inspection. Thus weather conditions, lighting, dampness, dirt, grease, and

other matter all affected how one “sees” an instance of RCF. In other words, the railway workers I observed during inspections often “satisficed” (Simon, cited in Vaughan, 1996); despite numerous constraints which made optimisation unfeasible, they had to make a decision on a rail’s fitness-for-purpose. This meant decision-making was often based on experience rather than clear-cut evidence. This argument suggests why some of the workers I observed used a measuring rule when others did not. Judgment, interpretation, and one’s own tactile know-how underpin methodology.

During another session of fieldwork (chapter six, section 6.5.2 page 169), I was given a clear cut example of how workers can utilise their own judgment in an effort to reduce risk whilst taking leave of their working schedules. The visual inspector during that night of fieldwork was scheduled to look at a weld – when we got to the site there was nothing to cause alarm, the weld was clear of cracking. However, instead of heading back to the van to travel to the next site, the visual inspector shone his torch further along the rail and decided to go on and look at further welds. He was not scheduled to look at any more welds or sites on this stretch of line, and he did not have to do what he was doing, but he “felt” that he should, saying to me that “it is curious”, thermite welds on this line are liable to cracking. Sure enough when we inspected the next weld there was a crack 20mm long. His judgement paid off and he completed an unscheduled risk assessment.

Once the visual inspector found the crack I was given a further example of the limits of *the document*. I say, in chapter six (section 6.3 page 161) that I perused industry documents looking at photographic examples of RCF. I did this to prepare myself for my observational field work, yet soon found out that such pictures were not able to give me the competencies required for effective and proper inspection. On one occasion, when I walked in front of the visual inspector on the permanent way to see if I could spot RCF first, I noted how I missed numerous RCF sites; he often pointed out sites to me after I had passed them by. Then, if it was left to me to measure the instances of cracking that was found, it was highly likely that I would have given a

false measurement. This is because of the aforementioned difficulties in measuring (i.e., shadows, dampness, dirt... etc).

During an inspection of an S&C (chapter six, section 6.5.6 page 175), I noted how the visual inspector's task was to give his opinion on a 40mm crack that a team of grinders had found the night before. A crack of this length should be categorised as "severe" and ultrasonically tested within 36 hours. Nevertheless, the inspector I accompanied was there to assess the possible reasons for the crack in the first place. His examination process took into account several features, some of which are noted in railway maintenance procedures – such as: look for missing bolts. He also noted how the switch blade was a little too high and that a stretcher bar was slack. Others, however, were not listed in the handbook, for instance he noted how there was too much ballast. The difficulty in reading information of the rail web (such as "place of manufacture"), he had learnt, meant there was too much ballast. Finally, he came to the conclusion that the crack itself could have been caused by all these things, but still, he concluded, it was only a surface crack and that it did not descend into the main body of the rail head.

10.5.2 Inverting "redundancy" theory

Due to the problems of inconsistencies with crack analysis and measurement, maintenance companies (when maintenance was completed by workers of individual companies and not by Network Rail personnel) had to deal with it in some way. Consequently, the maintenance company I worked with designed a system that was intended to account for the difficulties in crack measurement and analysis.

Going by the high reliability thesis, we are told that, if industrial organisations are to deal with technical problems effectively there should be in place "redundant modes of problem solving at operational level, and resistance to pressure to resolve or *rationalise* the process by adopting a single *best* way approach" (Roberts, 1993: 23). The maintenance company I worked with turned this idea on its head with respect to RCF inspection. Instead of operating multiple ways to overcome problems, it was decided to decrease and limit the amount of "modes of problem solving at operational

level”: the amount of individuals charged with RCF inspection was cut to one small group. In the north and east region an “RCF team” of three was separated from a wider spectrum of visual and ultrasonic operators of approximately a dozen. Furthermore the company “rationalised the process by adopting a single best way approach”

The process of reducing organisational systems to assess and measure RCF cracking fits better with the theory of Charles Perrow (1984). In his Normal Accident thesis, Perrow points out that by increasing organisational systems to fix problems, the system will only be aggravated further (1984). The maintenance company clearly thought that limiting the number of individuals charged with RCF inspection would decrease variables that could otherwise worsen the situation and create problems.

Despite the difficulties in rail fault measurement, however, the visual inspector is under pressure to note all instances of RCF correctly. This was one of the key reasons the first PWSI was issued after the Hatfield derailment. However, that document was issued in haste due to the inspection problems after the accident itself (Int: 03), and its content only added to the problems. One engineer explained:

...Because it [the first PWSI4] contained technical errors and confusion in some parts, issue 2 came up very quickly. Certainly issue one did allow for engineer’s judgement but because it was abused... more extreme than expected, issue 2 came out very quickly... which was all about “shall do in accordance...” and issue 3 as far as I am aware is not any different. (Int: 03).

However, having to work to a strict rule book can conceivably create a problem, as one engineer explained to me: “If we followed them to the letter we would have to shut the network down, as simple as that” (Fw: 07). This consequently meant that in an effort to follow the PWSI4 document accurately many track walkers often “cover themselves now by reporting possible RCF” (Fw: 02).

10.6 TACIT KNOWLEDGE AND ULTRASONIC INSPECTION

10.6.1 Operator judgement

My research shows that there are marked similarities between the SBB approach to ultrasonic testing and Railtrack / Network Rail's approach. On both networks, a comprehensive ultrasonic testing (UT) timetable is in place, and both programmes are underpinned by similar analytical processes such as traffic weight and speed. Both networks also utilise a rail-based ultrasonic testing unit. SBB operates two types (from different manufacturers) of ultrasonic test trains, whilst in Britain the UTU, and now the UTU2, operates. One difference between the two systems is that SBB complete an end of term assessment (the "Contrôle Partiel"), the company does not UT during the winter period – weather conditions make UT unfeasible during this time. In Britain there is year-round testing. There is also comprehensive manual testing of rails (especially at S&Cs in both countries), where again there are similarities. On both systems UT is typically completed by three-man teams – of which one man is the supervisor. However, testing is undertaken during the day in Switzerland, unlike the majority of UT work in most areas in Britain – where UT is typically completed during the night.

The principles of ultrasonic testing are well-known in the field of non-destructive testing and are applied often and routinely within the oil, gas, and nuclear industries. Yet despite working with seemingly clear-cut procedures⁹⁶, correct operation of UT equipment, which includes interpretation of its output, relies on the judgment of the operator which is often tacit in nature. The ability to decipher between a spurious and a genuine fault signal requires substantial interpretative skills on the part of the operator who must be dedicated to their work. A point which was agreed upon in both

⁹⁶ In the case of UT in the railway industry, the probe is placed on the rail and the ultrasound is transmitted into the rail via a coupling fluid, usually water. In an intact rail, the ultrasound beam travels through the rail to its maximum depth and is then reflected back from "rail bottom" to its origin at the probe. Here the mechanical vibrations are re-converted into electrical signals by the probe and are displayed on a cathode ray oscilloscope or computer monitor screen. The waveforms shown on the display are then analysed and assessed by the ultrasonic technician or operative. Where the maximum depth of the material is known, the technician will be looking for an uninterrupted signal from the boundary at the rail depth. Any discontinuity in the wave from the specimen's depth will suggest that there is an internal flaw.

Britain as in Switzerland: “The lads have to be interested in their work. If they come to their work with the aim of just getting finished, that’s no use... they have to be interested because it depends on their interpretation of that screen” (Int: 05) – “they have to take the job seriously, because they must always be looking” – (Fw: 31).

10.6.2 The relationship between rail disasters and the status of ultrasonic testing

The technological evolution of ultrasonic testing within the British railway industry was noted in chapter seven (section 7.1.1 page 185). Two rail disasters, one at Hither Green and the other at Hatfield (over thirty years later), had effects on ultrasonic testing in some distinct ways. Hither Green led to the widespread introduction of the pulse-echo technique, and Hatfield led to the development of the U14 testing procedure and the introduction of “the Sperry”. The crashes (specifically the Hatfield disaster) also had an impact on the “status” of the ultrasonic operator. Historically, ultrasonic testers had been seen as unwanted and unneeded as it was thought they only completed additional, superfluous work (Ints: 01; 02; 03; 05). It was then suggested that the actual role of the ultrasonic operator (i.e. looking for problems for others to solve) within the industry unintentionally gave them a negative and low status. Though this is exactly their safety-critical role, other workers may not perceive it in this way.

There has however been a change: since the Hatfield disaster ultrasonic testing is increasingly seen as a important requirement in rail maintenance by industry workers (Int: 05; Int: 25), and the historical impact on the level of esteem with which UT technicians are held has been, and continues to be significant. The identity and importance of the UT operator within the British railway industry and how it seems to relate to specific rail crashes appear to be closely connected. This point ties in closely with a thought of Gabrielle Hecht (1996). She suggested that areas of social research should analyse how risk interpretation and social activity with “stable” (indeed UT was described as a technical activity that remains “the same” by Int: 33a) technologies, say ultrasonic testing, are connected to and impacted on by on-going social, political and cultural matters.

The unfavourable status that was historically attached to ultrasonic testing seems to be abating. Its perceived importance has increased in recent years, especially since the Hatfield crash. The high skills of the operator that are required for effective testing are being increasingly acknowledged. The author of this thesis has again been concerned with analysing the constitution of these skills; how these skills are channelled; and how relevant skills are passed on to others new to the technology on both the British network and SBB network.

10.6.3 Getting to know things – some differences in formal training

Time after time it was explained to me, and often demonstrated quite explicitly, that in Britain formal training mechanisms (i.e., attending a two-week class for basic training at the Derby test centre) for ultrasonic testing only went so far: the course did not equip the new operator with all required competencies. Though the candidate learnt the basics and passed a test to gain a certificate, his⁹⁷ learning continued on site and in real situations. This is because knowing everything after the two week course and having the ability to complete all the checks and tests for defects is highly unlikely (Fw: 10). A similar outlook in Switzerland exists among SBB workers.

The SBB UT teams complete a one-week course as opposed to a two-week course and, what is more, the teams do not leave “their” section of the network for training – a representative of the training company visits them. This is different from the British where all prospective UT operators have to travel to Derby. Quite similarly though, SBB and British workers are examined on rail pieces with known flaws in them. Nevertheless, a clear difference is found in ideas concerning operator re-certification. Every two years the British worker must be re-tested on his learnt skills and competence prior to the expiry date of his current certificate. This is different to SBB’s re-test plans. UT workers, a senior member of SBB’s UT community told me,

⁹⁷ I only met male ultrasonic operators.

were retested “about every four years” (Int; 33a), and as another pointed out, this is because “experience is more important than training” (Int: 33).

Gaining experience, or “getting to know things” (Fw :16) is a valuable part of the process in becoming a competent operator in Britain and Switzerland. My findings point out that experience underpins proficient UT: the operator often makes decisions on a rail’s internal quality based on sound judgement and tacit interpretations that are typically informed by tacit social learning (Berger & Luckmann, 1966) in the UT group which is thus, in turn, referred to as “experience” (Fw: 11; Fw: 12; Fw: 16; Int: 33; Int: 05; Int: 25; Fw: 31). Having the competence (and confidence) to make risk assessments based on *immeasurable* or implicit knowledge about variable outputs (though internal rail flaws can be similar and can be broken down into types such as “taches ovaes” or “piping” – the signatures on the displays for each type of fault are not presented in consistent patterns that are immediately identifiable as a distinct “type”) requires training and collaborative group-learning over a considerable period of time. Such training encompasses several aspects, one for example, is how the operator will develop an ability to *see* where flaws are on the digital units, and he will also develop an ability to *imagine* where the flaws are inside the rail.

Finally, and most importantly, the training strategy involves the new operator becoming part of a group of experienced operators to learn role-specific knowledge (Berger & Luckmann, 1966). In this way the new recruit becomes exposed to the taken-for-granted (Berger & Luckmann, 1966), embedded way of doing things: we were shown how he is shown what traditions, cultures (MacKenzie, 1990), beliefs, and expectations guide work (Pool, 1997). Segments of Fw: 11 and 16 were particularly illustrative⁹⁸. Some interconnected issues arise here. It appears that “it is

⁹⁸ For instance: “So these things you learn through experience and by asking the others guys with experience and the knowledge. The first time I saw something like that I thought crikey, got a fault here, but you find out it’s otherwise, you rely on people with knowledge. Sometimes, the way they’ve battered the bolt – it can cause a slight chip and you can get a reading of that – but you get to know

through participating in the community that individuals learn the logic of the system and their own role” (Hutchins, cited in Sanne, 1999). Others (Douglas, 1982; Douglas & Wildavsky, 1982; Nelkin, 1985; Cutter, 1993) would suggest that such organisational mechanisms and interaction would generate community-dependent views and perceptions on risk. Whilst others (Goffman, 1959; Berger & Luckmann, 1966; Heath & Luff, 1992; Barnes, 2000; and Sanne, 1999) would add that this organisational system is likely to see members develop a shared orientation about the task at hand – this point does indeed seem to be true: “They look out for each other, that’s good. It’s important to have that. They discuss the problem, and they agree on the final action” (Int: 05).

An SBB worker also spoke about this subject in similar tones. It was suggested that the structure of the group was intrinsically important for the work at hand – indeed, it is thought that changes in the group’s personnel could have unintended and unwanted consequences: “They [the teams] are very good at their job, if you change things rapidly it could be a catastrophe, it takes a lot of time to make a little change” (Int: 33a). This comment suggests that at SBB there is a firm understanding that accidents can be caused by deficiencies in the organisational structure, and that industrial accidents are not always because of sharp-end human failures (Reason, 1997).

By being trained in this organisational set-up, he (the newcomer), will also note that these matters of worker collaboration act as a guide and become the basis for future work (MacKenzie & Wajcman, 1985). In Kuhnian and Mertonian terms, the ultrasonic operator becomes an agent who will help to ensure a technological paradigm is fulfilled and continue as a future frame of reference for problem solving.

these things. Even though you do the course at Derby and they assess you and you pass your test you still learn on the track” (Fw: 11). And: “When you’re at the training centre they do point out things like this to you, but still you have to see on site and be with others who ‘know’; by watching these guys who already know these things, that’s how you learn. These little things are important” (Fw:16).

10.6.4 The ultrasonic testing socio-technical system

Because of the way new UT operators are taught their trade and the way that experienced UT operators execute their work, the relationship between the social and technical is deeply interconnected making the boundary between the social and the technical unclear. For that reason, it is folly to say that ultrasonic inspection requires only step-by-step operation by compliant human users. On the contrary, my findings suggest that it is a unique form of interaction between the human operator and the machine that makes competent ultrasonic inspection possible. On this matter, Oudshoorn and Pinch (2003: 3) explain: “users and technology are too often viewed as separate objects”. Callon (1999: 183) had already pointed to the use of the actor-network theory, which was “developed to analyse situations in which it is difficult to separate humans and non-humans, and in which actors have variable forms and competencies”. With reference to my findings on ultrasonic testing methods we can see how the human and the machine interact: recall the comments about the role of tactile skills with “touch” and “feel” when testing: “For manual work contact coupling is preferred, because it gives the operator a better “feel” of what they are doing” (Sziland, 1982: 43-44).

My findings have shown how this important skill is again learnt through the medium of group work, but it was another technician that gave us a lucid description of the importance of “feel” when he said:

“Sound deflects at different velocities off different surfaces, it’s like throwing a ball of a wall, depending on how you throw it, it will bounce off at different angles and speeds, so the medium matters, pressing the probe on the rail with different force can change things” (Fw: 10)

10.6.5 The role of feeling and imagination

Quite clearly the role of the operator’s body is important, and here some will note the comparisons between the task of the visual inspector and the UT operator. Understanding *what to feel for* at one’s finger tips is all important when running fingers along a rail searching for surface irregularities (i.e., the fish scales effect), and the same level of importance can be ascribed to ultrasonic testing when the operator is

sliding the probe over the rail and is interacting with the machinery (cathode ray tube or computer digital display). In other words, competent UT requires a key link between operator and machine. The link, it seems, requires of the operator to conjure up an image of the ultrasonic sound wave travelling through the rail whilst running the probe over the surface: recall this section from Fw: 10.

It is at this moment that I guess UT operators need to use their imagination if they are to understand what is going on inside the rail with the pulsing ultrasonic beam. I asked about the role of imagination, and transferring what it is the operator imagines on to the visual display screen...

B: That's it!... It's simple trigonometry really... Training is done at Derby for a fortnight, for the basics, it wasn't until the second week that I suddenly got it... I understood what was happening with the probe and where the beam was inside the rail. Until then it was all over the top of my head.

In other words, it was when he “got it” that a unique, tacit link was made between the human and the machine; he had acquired the necessary tacit knowledge for UT operation. An example of what can occur if that key link fails to bond was illustrated on the night I was given the chance to ultrasonically test a rail: I remember how my untutored and clumsy “touch” with the probe made the reading of the signals on the unit unintelligible. Furthermore, imagining *where* the ultrasound wave is *in* the rail and its direction of travel is imperative: visual aids are hence required to help workers understand. At the Derby test centre I was shown how a see-through rail head had been manufactured and a red beam was fired into it. This model replicated how an ultrasound wave travels. Furthermore, when I was on site in Britain and Switzerland, workers at first introduced me to ultrasonic testing by using visual aids to “describe” how ultrasonic testing works. For instance, they scored on the rail with chalk or placed a pen against the web to show me the angle of the sound wave. Securing this image in the mind's eye (Ferguson, 1993) and by thinking “visually” (Vincenti, 1990) and transferring the image to real life situations, I gathered, is what an UT operator must do whilst caressing the rail's surface with the probe.

Linking the movement of the probe and its position upon the rail, whilst accounting for the sound wave's likely proximity to internal features like boltholes, directs the image of the sound wave's journey that is being played back in the mind of the operator. Knowing how hidden, internal material can disrupt the wave's journey to the rail bottom and back to the probe has to be visualised in the operator's mind.

Connected to this area of work of the UT operator is the thought of Vincenti (1990) who argued that visual aids [such as computer generated images like the signature on UT digital display] are only effective tools if the operator *knows how* to interpret them. Accordingly, as Canfield (1981), and Dreyfus and Dreyfus (1986), would suggest, UT is more about *knowing how* rather than *knowing what*. This thought was drawn out most obviously when testing at rail ends where bolt-holes are found (see chapter seven, section 7.3.1 page 205) and at S&Cs where bolts can be hidden – most notably on the Swiss system (see chapter nine, section 9.7.5 page 289).

The sociology of knowledge theory suggests that society (in this case an ultrasonic testing community) and knowledge are not detached. Recall the words of Collins (1982), with my [inclusions]: “The process of learning [how to ultrasonically test a rail, which we now know involves extensive group work and colleague collaboration], or building up tacit understandings [i.e., “feeling” the rail *with* the probe and how this constructs images in the mind's eye], is not like learning items of information, but is more like learning a language or a skill” – which, Faulkner et al (1997) and MacKenzie (1996b) reminds us, is only transferred by social and personal interaction. Thus, as Law (1991: 20) explains: “knowledge and technical systems cannot be understood unless the simultaneous reconstruction of the social context of which they form is also studied”. Accordingly, this thesis has been about “the socio-technical system”. Schmid et al (1994) tell us that for the workplace to operate effectively during periods of alteration, relevant changes must be made throughout the system: optimisation of the social and technical systems must be done in conjunction.

My research uncovered some difficulties when changes are implemented and alterations are made to one side of the socio-technical system – namely the

introduction of the PCN (Personal Certificate of Non-destructive testing). With the PCN, general UT theory for new UT candidates has become more intense: UT operators who have been in the industry for years have become very competent and highly skilled operators, despite their lack of theoretical knowledge. Their basic training, combined with their years of experience and knowledge development, has produced in them a sound understanding of the UT process as associated with rail testing. However, for them to remain in the industry, they have to be re-tested to PCN standards every two years, which involves learning new material which some, it is feared, may struggle with (Int: 05; Int: 25). The thought is that, with the introduction of new technology, new training structures on technological matters should take account of the working culture that exists already. The PCN type qualification should not be “added on” and imposed on people. When alterations are made to training strategies there must be reference to the current experience base and current modes of decision-making that are encapsulated within the socio-technical system.

10.7 TACIT KNOWLEDGE AND MANUAL RAIL-GRINDING

10.7.1 SBB and Network Rail: technical similarities and cultural differences

SBB and Network Rail (as Railtrack did) both utilise a train-based grinding system, but unlike Network Rail, SBB does not employ teams of manual rail-grinders.

Train-based rail grinding is the only regularly used method of grinding on the SBB network, and the timing of this is of the utmost importance. Initial grinding must be done within the first two weeks of a new rail being laid, thereafter the timing for further grinding has to be closely examined: any grinding that is done is only done if required (Int: 34; Fw: 32; Fw: 36). The use of manually operated rail-grinding machinery on the SBB system is limited to the use of the so-called de-lipper when any irregularities on the rail's gauge face (i.e., lipping) are preventing precise measurement of the gauge (Fw: 32). Regular manually operated grinding of the rail is simply not done anywhere – it is too expensive when set against any short-term or long-term benefits (Fw: 31; Fw: 32; Fw: 34; Fw: 36; Int: 34). The approach to rail-grinding on the Network Rail system is almost completely different apart from the practice of grinding new rail. Thereafter, train-based grinding should be planned on a

cyclic basis (PWSI4, Network Rail, 2003). A further difference, and the most marked difference, is the role of manual rail-grinders.

After the Hatfield disaster it was decided that a full manual rail-grinding programme of S&Cs should be implemented and, the idea was fully supported by groups such as the Wheel / Rail Interface Systems Authority. Regular manual rail-grinding at S&Cs is therefore a new activity: the only form of grinding that was regularly done prior to this on the network was completed by a train-based system (The Speno), however, the use of this decreased throughout the 1980s as its perceived worth dwindled and it was felt to reduce the useful life of rail. Manual rail-grinding was also done, but was typically by welders during the normal course of their work – after welding, the welder typically has to grind off the excess (Int: 28; Int: 09). In the main, however, regular manual rail-grinding of S&Cs by specific teams trained for that task alone is a new addition to rail maintenance in Britain. How industry leaders in Britain framed the problem of RCF has had an important bearing on what is now being done about it (Nelkin, 1985). The principal method to control RCF, they determined after consulting “world experts” (PWSI4, Network Rail, 2003)) is through regular grinding. In Switzerland, despite experiencing the same problems with the wheel / rail interface, the way SBB leaders framed the problem suggested that they should rely extensively on their own experience rather than scientific findings (Pfarrer, 2002: Conference paper).

Pool (1997: 5-6) suggested, after his research found differences in how different countries managed nuclear power, that the explanations for such “different outcomes cannot be found in engineering, since the countries are essentially using the same technology”; this comment fits with the thrust of my thesis. The differences in rail-grinding between Switzerland and Britain, Pool (1997) and Douglas and Wildavsky (1982) would state, are due to culturally based world views. Outcomes from risk assessment are always going to “rest upon the relevant community” (MacKenzie, 1996b). What is more, these issues also help us reject the traditional model of the science and technology relationship (Barnes & Edge, 1982). The model suggests that accepted, systematically constructed, scientific knowledge underpins engineering

knowledge. If this is the case, rail-grinding would be administered (or perhaps not if scientific findings *proved* that it was futile) after “working out and realizing the implications of scientific theories” (Barnes & Edge, 1982: 148). Instead, we can surmise that the differences between the two railway industries’ approach to rail-grinding is because railway engineers “possess their own distinct cultural resources which provide the principal basis for the innovative activity” (Barnes & Edge, 1982: 150). But what is the distinctive difference? A tentative argument may be that the socio-historical cultural influences at SBB suggest that work should be based more on experience rather than science. In Britain, there has been a move towards a science/procedure based approach. Perhaps, after privatisation inadvertently discarded valuable knowledge that was locked up in the heads of workers, it was thought that the ensuing knowledge gap could be bridged by scientific formulae and application. In chapter four (section 4.2.3 page 119) for instance, I noted how the use of computer packages to assess and monitor rail conditions is increasingly sought for in Britain, whilst SBB rely on an experience-based model illustrated in chapter nine (section 9.4.1 page 266).

10.7.2 The activity and aims of manual rail-grinding in Britain

There is however an irony. If, in Britain, the decision to implement manual grinding of rail at S&Cs was informed more by explicit scientific principles, it is ironic that the actual process of manual rail-grinding relies extensively (arguably entirely) on subtle key work processes that are implicit and tacit in structure. In this section sociological concepts discussed in earlier sections are employed once more to shed light on implicit mechanisms that enable a group of workers to successfully grind a rail.

Chapter eight showed how hand grinders have six aims to fulfil whilst grinding a rail. They have to: remove any lipping that may be covering cracks; then they have to “MPI” it (magnetic particle inspection) to see if there is any cracking that may be missed by the naked eye. If so they then have to remove the cracking; and they have to regain the profile of the rail to accepted standards; and they have to blend in the ground rail to the surrounding rail that was untouched by the grinder (so as not to cause a sudden dip for passing vehicles) and, finally they must re-MPI it. Removing

cracking, re-gaining the profile, and blending in the rail are grinding processes that have to be done simultaneously. Completing the whole process for just a few metres of one rail typically takes a whole shift (approx. six hours). The achievement of these six aims must be completed within precise parameters: the teams cannot remove more than five millimetres of rail with the coarse grinding stones, and the rail must be in a suitable operating condition at the end of the shift so as to prevent line closures and delays. These conditions can be impacted on by further matters. There can be problems with the technicalities of a possession (opening a switch blade can cause problems, and letting traffic pass such as the grinding train and track patrollers in the Land Rover can cause delays).

In total, these are the environmental conditions of a possession in the railway industry when grinders have to complete delicate work that is controlled by tacit skills and mechanisms.

10.7.3 Needing someone who “knows”

Given the novelty of grinding S&Cs as an ongoing maintenance procedure, training workers specifically for the task is an obvious pre-requisite but, firstly, the actual training structures had to be put in place. This posed some difficulties as there was virtually no experience to fall back on, one instructor for instance put it this way: “But because there was no real experience in grinding S&Cs like this, I was learning about it at the same time” (Int: 28). To assist the situation, the IMC I worked with turned to a specific group of people who were likely to grasp the technicalities of grinding a rail quicker than others: namely welders. These men: “have a history in grinding – they need to know how to make shapes ... they need to have had a history of using hand grinding machines”. (Int: 28).

There is a clear connection between my findings and Harry Collins’ findings (1982) regarding the construction of a TEA laser. Collins found that successful construction depended on someone in the laboratory who *knew* where to look for problems. This person was both a carrier and a source of knowledge and, by having him or her in the laboratory they were thus able to transmit “know-how” to others less practised. The

link with manual rail-grinding is clear: relying on, and trying to teach, someone without a background in metals is likely to prove unsuccessful (Int: 09), as “you can’t take Joe Bloggs off the street whose got experience in electrics and ask him to grind a rail, he maybe doesn’t understand metal... or the process, so he’ll never get a good result” (Int: 29). If we paraphrase Faulkner’s (1997) take on Collins’s work and manipulate it for this thesis we get closer to the point: A team of manual rail-grinders need to know someone who had used a grinding machine before, they needed this person’s tacit knowledge. They needed at least one member of the team to know where to look for problems and who was likely to say, without formulating explicitly, *have you looked at component x?* By asking such questions and by simply working in their normal way, the source is likely to pass on tacit skills which often involve the transference of judgemental skills (MacKenzie & Spinardi, 1996).

During rail-grinding, team members often pause for thought to judge what is required: they have to assess what grinding strategy will work and which will not. Indeed, the whole point of the rail-grinding team’s work is to solve a problem: grinding out cracking or re-profiling a deformed rail. Whatever it is, the team of grinders at the start of a shift know that they have to tackle a problem and what is more: “There’re different problems and they all have different methods for grinding the problem” (Fw: 15).

10.7.4 Rail-grinding paradigms

The teams continually assess varying problems. However, it tends to be the case that the teams fall back on known, tried and tested grinding strategies. Learnt grinding processes are typically exploited and often extended by the individuals and the teams. For instance, the teams have learnt that you cannot just attack high spots on the rail: “you can’t just go at it, have to take it easy, it’s a gradual process, if you went at the rail you would just flatten it, it’s got to be done gently” (Int: 28). And what is more: “There’re different methods for grinding each rail problem ... it all depends on the type of problem... the initial problem tells you how to grind” (Fw: 15). Elsewhere it was pointed out to me how the actual location of the rail itself can shape how grinders approach the problem – if the S&C is located on a curve, the cant deficiency comes

into play and grinders may opt to digress ever so slightly from the standard template profile. In this circumstance the grinders learnt to work *from* the running band that is created by passing vehicles instead of the running band of the template – the difference between the two is minute, yet makes a significant difference in terms of future work loads. In these instances there are clear examples of workers learning the limitations and advances that can be made with the technology at hand.

The connections with Kuhn's thoughts on paradigm as a "concrete problem solution" (Kuhn, 1970) are obvious. Workers, for instance, have achieved numerous technical objectives that required strategies not learnt during formal training. For example, depending on problems they may not grind high spots immediately, but might *work in* from one of the faces (Fw: 15), or they may grind the rail in one sweep, or metre by metre (Fw: 13), or they may grind from the running band instead of the template (Fw: 18), and they may lift the machine manually to blend in the rail instead of using the machine's functions (Fw: 14). Each of these ideas has been conceived over time and the skills to accomplish them have been honed during the same period. Of importance, however, is that each practice should be viewed as an achievement upon which future work is modelled (MacKenzie & Wajcman, 1985). In Kuhnian terms, the workers having learnt the basics of grinding – which involved getting to know the machine (Fw: 18) and finding out how to make shapes (Int: 28) – and once understood they have attempted to extend and exploit grinding methods in a variety of ways (Kuhn cited in Crombie, 1961).

10.7.5 The culture of manual rail-grinding

The actual mechanisms that underpin these work practices can be illustrated with reference to the work of Merton (1957) and MacKenzie (1996a). Firstly, Merton told us that "definitions of a situation become an integral part of the situation and thus affect subsequent development" – for this thesis it is how grinding operators define individual rail problems that dictates how each should be ground. This is clearly what occurs when a team approach their work and define (or "scope", Int: 28) how grinding should be executed prior to any actual grinding. What is also the case is that this decision-making process informs future work for other nights. Improvements in

manual rail-grinding techniques come about by the extrapolation of identified limitations and possibilities into the future and, importantly, its continuance becomes embedded (MacKenzie, 1996a) in the team. It becomes an integral part of what may be called a taken-for-granted workplace culture (Berger & Luckmann, 1966). At this point arguments can be put forward for the idea of co-constructionism (Murdoch, 2001). Indeed, it seems that grinding strategies were not simply slotted into a pre-existing cultural context – instead it seems that grinding knowledge and culture were being developed simultaneously. When talking about manual rail-grinding, we should refer to, in Law's (1991: 8) words, "the social and the technical all in one breath".

Culture, we know, is formed by the meshing together of customs, norms, conventions, language, etc. Each of these components must be learnt by group members if the group is to continue performing its function (Giddens, 1993, Abercrombie, 1984, Cohen, 1994, Cohen & Taylor, 1992). In terms of manual rail-grinding, we also find that, collaborative (often tacit) social processes of learning (Berger & Luckmann, 1966) about the technology shape the group's work mechanisms and enable the simultaneous construction of a corresponding culture.

The argument for this stems from the fact that manual rail-grinding is a new activity, and that problems in teaching the profession were caused because there was no "real experience" (Int: 28) to refer to. There was (in part) a semblance of a pre-existing grinding community which was made up of welders, but there was no dedicated S&C manual rail-grinding community – it had to be constructed. Consequently as the grinders learnt the trade they also developed a community and individual teams within developed their own culture ("Different teams, different guys have their own way of doing [manual rail-grinding]" Fw: 13) but, as learning is ongoing, the cultural make-up of the teams is constantly extending to fit the requirements of the trade. This is most notable in terms of communication. Communication typically involves precise linguistic terms (Mannheim, 1982). Yet, the environment of the railway during a manual rail-grinding possession makes verbal communication impossible at most times – generators are noisy, so too are grinders, and workers also wear ear-protectors and masks over their mouths. Talking to each other lucidly is simply not possible.

Communication, instead, had to adapt to the surroundings, and gesticulation transpired as the most convenient mode to “converse”. Specific hand signals between team members let each other know about the progress of work at that point in time.

It should be pointed out, however, that even if manual rail-grinders worked in quiet conditions and were able to talk to each other about their task – gesticulation would still be required. Grinding a rail requires what Vincenti (1990) and Ferguson (1993) would refer to respectively as “visual thinking” in the “mind’s eye”. Though there are precise aids such as the template with numerical divisions, all grinding relies on judgment, experience, interpretation, feel or, in short, tacit knowledge. Knowing how many passes of the grinding stone are required to remove a high spot; knowing when and “how” to lift the machine for blending in rail; knowing how grinding at one point on the rail will affect the rail in the future and in terms of the whole process; and knowing how a rail will “look” once the grinding machine has passed, are all essential parts of the activity, but explaining and describing each instance in a coherent instructive, succinct manner with precision cannot be done. Oral communication is used often when group members are together, say when checking the template’s fit on the rail, but the terminology is imprecise and vague. Because of the spoken word’s failings, hand signals are used. Again, by resorting to tactile skills, the men caress the rail this way and that, and in doing so they mimic the direction that the machine should take when next operated. Such gesticulation which requires a shared understanding of tactile knowledge, make up for the inadequacies of speaking.

To understand the meaning of communicative features such as these, however, group members must have a shared understanding which involves a common orientation to the task (Sanne, 1999; Goffman, 1959). As one grinder told us: “You need skilled men for this job, and you need men who care” (Fw: 18). To get to such a level of shared understanding, Berger and Luckmann (1966) suggest, involves secondary socialisation – that process whereby individuals learn role-specific knowledge. Similarly, Sanne’s (1999) take on Heath and Luff’s (1992) concept of distributed cognition, can be used to back up some of my findings. For instance, we know that grinding a rail is a lengthy and tiresome process that requires team members to take

turns. However, each worker, when taking up his post at the wheel of the grinding machine, must know “where” the last operator *got to* in terms of the whole project. Each operator must “know” what one must do now and, given that it is not immediately perceptible by simply looking at the rail, operators must have a shared understanding of the situation.

Having a shared idea of *where* the rail must be ground and in what order parts of the rail profile should be attacked with the machine is paramount – each individual has to visualise and coordinate the process for themselves but it must be in tandem with his team mates. Each operator’s visualisation adds to an appreciation of the overall situation, and assists with the complete work situation (Sanne, 1999). Ultimately, a working division of labour in the team of manual rail-grinders emerges where each worker knows *what* to do and *how* in a complex socio-technical system (Callon, 1999). We can see how important shared tacit understanding is for members of the teams if we imagine the work units consisting of individuals each working in his own way. If the team members looked at the rail on their own, and assessed where it should be ground on their own, and adopted their own procedures and utilised them in a different order, the outcome would very likely be very different. If there was simply no communication between the team members and no sharing of aims, then grinding a rail successfully would, in all likelihood, be impossible.

10.8 CONCLUSION

This sociologically-based thesis has been about the technological knowledge required for three key activities that form part of track maintenance in Britain. In sections of the thesis, RCF has been referred to and utilised as a heuristic device to guide analysis of visual inspection, ultrasonic inspection, and manual rail-grinding. From this departure point, several issues emerged that became of empirical interest.

History and organisational change, it soon became clear, were going to be important issues. Whilst researching this area of the thesis I realised that real, physical, on-site, activities that characterised railway maintenance during BR’s reign were underpinned

by experience. How workers *knew* what was to be done was often driven by experience. Discussions on gaining experience logically referred to how work was organised – the make-up of the regional baronies, it transpired, showed how knowledge was transmitted from experienced worker to new recruit. By fast-forwarding to the current day, we gained a strong idea as to what exactly that knowledge consisted in by analysing the many skills involved in visual and ultrasonic inspection. Two interconnected issues were of importance here. Effective management of the permanent way requires local knowledge for local problem spots and such local knowledge, underpinned as it is by experience, is often tacit in nature.

As has been documented by several sociological studies however, organisations that have to control workers involved in technological activities can struggle because of the very nature of the work. The contradiction is simple: how can organisation-leaders tell decentralised workers how to work (i.e. by transmitting instructions from a central-base) when often the work in question cannot be verbally communicated even at face-to-face level? If efforts to overcome this contradiction involve the issuing of even more documents, confusion among a workforce is likely to be exacerbated. We saw this clearly happening in the British railway industry, most notably after privatisation.

In terms of RCF alone, we saw how the workforce was confused by instructions in the days and months following the Hatfield disaster. During this period, the British industry in a sense performed like Charles Perrow's *pushmepullyou* analogy. Perrow classifies railway industries as tightly coupled and exhibiting linear interaction (1984: 332). When the tightly coupled parts of the system fail, they will fail in comprehensible and expected ways. We need to dwell on a seemingly taken-for-granted, yet hugely important point: such failures will be comprehensible *to whom?* Prior to privatisation and prior to those experienced workers leaving the industry (with the knowledge locked up in their heads), failures in some parts of the permanent way were likely to have been comprehensible: a decentralised workforce able to address the problems *was* in place. But when large parts of this workforce left the industry there was a knowledge gap and a subsequent lack of experience. This

logically meant that what were previously well-known problems and failures were *now* not comprehensible to many of those who came to the industry anew. In a sense, the system, in Perrow's terms, shifted from one that was linear to complex – problems and failures *became* incomprehensible. The nature of the technology in itself had not changed: the technology was not *more* complex as a result of organisational change. On the contrary, it was the complicated organisational change that involved the intake of inexperienced workers who did not *know* the technology that made it incomprehensible during times of technical failure. Then, after shifting to this state of affairs, the industry exacerbated the problem by issuing thousands of maintenance documents as it sought more control from a central base than had been the case when BR was in control.

Ultimately, the post-privatised set-up in Britain saw the implementation of a *pushmepullyou* model. The nature of the permanent way requires decentralised decision-making, but more control from a central base was striven for – inherent conflicts, Perrow tells us, would naturally occur, and what is more, discarding a knowledgeable workforce, we can add, only aggravated the problem. The SBB model of 23 small regions, on the other hand, points out how centralised and decentralised authorities can be slotted together without undue conflict if the role of experience is fully acknowledged and accommodated.

In my thesis I have shown how tacit, experiential, tactile knowledge was required for rail maintenance before and after privatisation – my ethnographic findings have pointed out that the critical importance of tacit knowledge remains today, in the privatised set-up. Effective rail maintenance can only be completed by experienced workers who often rely on tacit knowledge. Despite the disruption to the workforce in the wake of privatisation, I found that the groups of workers I spent time with (such as ultrasonic operators, but especially manual rail-grinders) are, in their own way, building up once more a personal asset register that they are knowledgeable about. Individual visual inspection teams are building up a catalogue of rail problems and the likelihood of their location and severity. The teams, I found, are continuing to learn about the permanent way and its associated, localised peculiarities. Manual rail-

grinders are in a constant learning curve also and, what they have learnt is often tacit in nature and only comprehensible to and applicable by the group that constructed the knowledge. Quite similarly, ultrasonic operators, despite formal training learn from the group. New recruits typically learn and pick-up things from experienced workers. Essentially, during my research, I note how the development of know-how is a project for the individual and the group – group members often learn together and use what they learn as a guiding mechanism for future work – and what they know is often tacit in nature. Effective rail maintenance relies on socially constructed, tacit knowledge.

10.9 RECOMMENDATIONS

In light of my findings, some recommendations for improving aspects of railway track maintenance in Britain can be put forward.

The regional baronies, that characterised the organisational set-up of BR's maintenance systems, appear to have used an approach to railway track maintenance that was similar to today's organisation of the activity at SBB with its small maintenance teams within each of the 23 districts of their network. I believe that lessons can be learnt from the current maintenance systems that are in place at SBB and, I would suggest that the maintenance systems that underpinned BR's stewardship of its assets can be improved upon.

Despite alleged differences in the quality and art of work that existed between the baronies, devolution of maintenance responsibility to small teams under local and regional chiefs who have the authority and, probably most importantly the trust of centrally-based senior managers to make decisions offers the possibility of creating an effective working culture of safety. Such decisions would include cutting or increasing inspection levels as and when required. An increase in trust could also cut levels of bureaucracy and this would result in a significant decrease in the amount of paperwork required to be completed by track workers. A decrease in the amount of often unnecessary paperwork would not only increase the time for track workers to "work" on the track, but, in all likelihood, workers would simply enjoy their work

more: as I found in Switzerland, workers enjoying their work was seen as highly important and effective. Indeed, in Britain, paperwork appears to be the bane of many supervisors' working life. Following instructions to the letter at times was confusing; completing forms was difficult, instructions were often unclear or impractical during maintenance activities (most notably for visual inspection and crack categorisation) and, on occasions, workers noted duplication.

Cutting paperwork, which includes both the issuing of instructions and forms to be completed, requires a substantial level of trust and belief in the competencies of geographically dispersed workers. SBB therefore created a central training scheme where workers were immersed in an environment that characterised the railway industry as a whole. Apprentice welders, for instance, trained with and consequently developed some knowledge of the work of those who operate the traffic, of electrical engineers, and of those who operate the signalling. Though appearing to be unnecessary and time-consuming this was, on the contrary, hugely important. This set-up gives each worker a deep sense of what is required to allow a railway system to operate efficiently and safely. Ensuring that "their" part of the systems is working in line with the standards becomes imperative and a sense of pride is generated which, in-turn, helps to sustain the working culture of safety.

Network Rail, I would suggest, should look at developing a training scheme for newcomers to the industry that will immerse apprentices into a training environment that simulates and accounts for all aspects of the railway industry – hand grinders, for instance should not be trained solely on grinding as it was the case during my research period. Crudely speaking, grinding personnel should be introduced to traffic operation, signalling, etc and the problems that can arise due to knock-on effects from track maintenance problems. In this way new recruits can develop an understanding of the "whole" that is the railway system: they will see their work as an integral part of a deeply interconnected system. The current system in Britain does not account for this, and this arguably goes some way to explaining the negative feelings that exist between train operators and track maintainers. The two parties understand on a somewhat superficial level what each other has to do, but the two do not discuss (at

all) intrinsic needs and requirements, as and when contingencies arise. At SBB the position of the Integrated Maintenance Manager was fashioned to account for this need. A clear cut communication channel exists between train operators and track maintainers – the two are able to discuss their needs: and an “us and them” situation (which characterises the relationship between the two in Britain) has not emerged, but rather a considerable level of respect and understanding. Trainers at Network Rail’s new apprentice training centre in Portsmouth should heed this advice.

It should be underscored, however, that implementing such changes would involve a long term project. Working cultures cannot be changed over night. Current workplace cultures must be taken into account: i.e., recall how the PCN certificate created problems for older UT operators. However, implementing a training scheme of the type suggested above could put in motion a socialisation process which, over time, could become self-fulfilling and self-sustaining. Again, crudely speaking, as workers gain a sense of how “their” work matters and how it affects the “whole” of the industry – a sense of pride, commitment, and ownership could come to underpin and guide working activities. The positive traits of the former BR maintenance structure may thus be recreated without the risk of re-introducing some of the negative aspects of the BR culture. Furthermore, as knowledge develops, in the sense that we have seen how hand grinders have developed knowledge and how UT operators develop knowledge, there will be less of a need for an instruction-based method of communication between geographically dispersed workers and centrally based senior managers.

By implementing structural change to encourage such developments, Britain’s railway network could reap rewards in the long term.

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